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Department of Agriculture and Fisheries
SEA FISHERIES INSTITUTE

Republiek van Suid-Afrika
Departement van Landbou en Visserye
INSTITUUT SEEVISSERYE

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FISHERIES BULLETIN
13
VISSERYE-BULLETIN

CONTRIBUTIONS TO OCEANOGRAPHY AND FISHERIES BIOLOGY
BYDRAES TOT OSEANOGRAFIE EN VISSERYBIOLOGIE

CAPE TOWN KAAPSTAD
1980

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On 1 April 1980 the Sea Fisheries Branch of the Department of Industries was transferred to the enlarged Department of Agriculture and Fisheries and renamed the Sea Fisheries Institute.

Op 1 April 1980 is die Tak Seevisserye van die Departement van Nywerheidswese na die vergrote Departement van Landbou en Visserye oorgeplaas en tot die Instituut Seevisserye herdoop.

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1980

INVESTIGATIONS INTO METHODS OF DETERMINING ORGANIC POLLUTION IN SEAWATER. 1. A COMPARISON OF TWO STANDARD METHODS FOR THE DETERMINATION OF CHEMICAL OXYGEN DEMAND

P. CHAPMAN

Two methods for determining the chemical oxygen demand (COD) of seawater samples were compared. Results show that the method of Jirka and Carter (1975) cannot be used on such samples. The method of Michel (1972) appears to be reproducible to ± 5 per cent at levels below 200 ppm COD, and to ± 10 per cent at higher levels.

Twee metodes vir die bepaling van die chemiese suurstofvraag (COD) van seewatermonsters word vergelyk. Die resultate toon aan dat die metode van Jirka en Carter (1975) nie vir sulke monsters gebruik kan word nie. Die metode van Michel (1972) lyk reproduseerbaar tot ongeveer 5 persent op vlakke laer as 200 dele per miljoen COD, en tot omtrent 10 persent op hoër vlakke.

It has long been known that the oxidation of various waste substances dissolved in water can seriously lower the oxygen content of the water system and that this can, in its turn, have a deleterious affect on aquatic life. Although the biochemical oxygen demand (BOD) test has long been known as a measure of the biodegradability of a waste (A.P.H.A. *et al* 1965), it requires a long analysis time and gives poor precision and accuracy (Ballinger and Lishka 1962). Thus the chemical oxygen demand (COD) test was developed (Moore *et al.* 1949) to give a value for the ultimate oxygen demand of a waste and thereby a measure of its polluting power.

The commonly used method for the determination of COD (A.P.H.A. *et al.* 1965) depends on the oxidation of the various organic compounds present by boiling in a mixture of chromic and sulphuric acids. Excess chromic acid is added initially, and the excess is backtitrated after reaction with ferrous ammonium sulphate. The amount of oxidizable organic material present is proportional to the amount of potassium dichromate consumed. Unfortunately, not all compounds are oxidized to the same extent, straight-chain aliphatic compounds, aromatic hydrocarbons, and pyridine being especially resistant. This may be alleviated in part by the use of silver sulphate as catalyst (Moore *et al.* 1951), but results are still not satisfactory for aromatic compounds. Attempts at finding an alternative to this expensive catalyst have met with no success, although Moore (1976) did find that economies could be made on the amount of silver necessary for oxidation.

Potassium dichromate does not oxidize only carbon compounds, and other species that are oxidized under these conditions include nitrite and other compounds containing nitrogen in reduced form, ferrous iron, sulphite and sulphide. These are the main interfering substances in freshwater. In seawater, there is the added complication of chloride, which exists in high concentrations and is readily oxidized to chlorine. Attempts to use a different oxidant, such as cerium (Moore 1976) have not alleviated this problem, and mercuric sulphate has been used routinely (Moore *op. cit.*, Dobbs and Williams 1963, Baumann 1974, Jirka and Carter 1975, Michel 1972) to complex the chloride and remove it from solution, since it has been shown that the degree of oxidation of chloride is not predictable in practice.

Although colorimetric analysis of the excess dichromate has been used by Chaudhuri *et al.* (1973) and Jirka and Carter (1975), only samples containing low concentrations of chloride could be so analysed. For highly saline samples, the titration procedure used in the standard method was thought to be more accurate because of the high concentration of dissolved salts, and also because chloride appears to exercise a variable affect on the reaction (S. A. Mostert, Sea Fisheries Institute, personal communication).

Because the method was to be used for the routine screening of many samples, the chloride correction method of Baumann (1974) was considered too tedious to be used. Instead, the methods of Jirka and Carter (1975) and Michel (1972) were compared. The latter method requires a small sample (10 mℓ) with a large excess of mercury salts to complex the chloride. The heating step is accomplished by adding concentrated sulphuric acid to the reaction mixture and utilizing the heat of dilution. The reaction is thus completed in about 20 minutes, compared with the two hours

specified by A.P.H.A. *et al.* (1965).

The method of Jirka and Carter (1975), on the other hand, is a semi-micro method designed to cut down on the expense of reagents and on the volume of toxic wastes produced. For instance, sample size is only 1,5 mℓ and the total reaction volume is 7,5 mℓ. Heating is accomplished in screw-capped test tubes in a heating block at 150°C for two hours. The method has a claimed accuracy of ±1 ppm COD and a range of 0-1 000 ppm.

METHODS

Reagents were prepared according to the recipes given by Jirka and Carter (1975) and Michel (1972), using potassium hydrogen phthalate as the COD standard. All samples were run in triplicate and titrations performed on a Radiometer Autotitrator.

RESULTS AND DISCUSSION

In the experiments using Jirka and Carter's (1975) method, a preliminary study was made into the effect of salinity on the response of the method. The results of this are shown in Table I, where it will be seen that there is a response to chloride at all concentrations and that this is not predictable.

Table I: The apparent COD of various chloride solutions analysed by the method of Jirka and Carter (1975) — mean of the results

Chloride concentration (ppm)	COD (ppm)
1 000	80
2 000	161
3 000	173
5 000	348
10 000	1 127

Samples were then taken with chloride concentrations of 2 000 and 5 000 ppm, and spiked with the COD standard at various concentrations. These were again measured and the results are shown in Table II. The difference in the blank value is partly the result of carrying out the analyses on separate days and partly caused by doubling the amount of digestion solution used in the second case in an attempt at increasing the complexation of chloride. From Table II it will be seen that, although the increment obtained from standards containing 2 000 ppm chloride is close to that expected (maximum error at 600 ppm = −7 per cent), at a level of 5 000 ppm the error is greatly magnified.

Table II: The effect of chloride concentration on the COD of a saline solution analysed by the method of Jirka and Carter (1975)

Chloride concentration (ppm)	COD added (ppm)	Total COD found (ppm)	Increment due to added COD (ppm)
2 000	0	43	—
	200	253	210
	400	424	381
	600	612	569
5 000	0	133	—
	200	270	137
	400	442	309

For this reason it was decided to dilute all natural samples by a factor of 10 to bring their chloride content to < 2 000 ppm chloride, despite the fact that this would result in an order of magnitude decrease in sensitivity (normal seawater contains about 19 000-20 000 ppm chloride).

The second part of the work consisted of comparing the two methods with a series of standards. Sodium chloride solutions were made containing up to 400 ppm COD, and analysed simultaneously by both methods. Five samples of each standard were taken to allow a representative mean and standard deviation to be determined.

During this work, the decision was taken to halve the concentration of ferrous ammonium sulphate used in titrating the samples analysed by the Jirka and Carter (1975) method in an attempt to improve the reproducibility and to cut down on the error. While improving replication, this was not particularly successful in the latter aim. Samples used in the Jirka and Carter *(op. cit.)* method were diluted ten times with double glass-distilled water.

For Michel's (1972) method, the amount of dichromate in the oxidizing reagent was doubled in an attempt at increasing the upper limit of this method. This was necessitated by the initial results from the Jirka and Carter (1975) method, because establishing an area of overlap between the two

nethods was thought desirable.

Results are shown in Table III, and it is evident hat the Jirka and Carter (1975) method will not e of any use in the analysis of seawater containing ess than 500 ppm COD. The other method would ppear to be accurate enough for routine use, lthough note should be taken of the drop in esponse at higher COD levels. The reason for his drop is unclear, but it may be that the heating tep, which makes use solely of the heat generated y diluting concentrated sulphuric acid, is not dequate to cope with the oxidation of higher oncentrations of organic matter. Michel (1972) nly worked up to levels of 200 ppm COD.

able III: A comparison of two methods for determining COD by means of potassium hydrogen phthalate standards in sodium chloride solution

COD added (ppm)	COD found (ppm)	
	Michel (1972)	Jirka and Carter (1975)
0		386 ± 165
50	51 ± 1,8	199 ± 246
100	94 ± 4,0	207 ± 177
200	193 ± 4,6	294 ± 103
300	271 ± 2,2	494 ± 243
400	363 ± 17,2	437 ± 100

Finally, seven natural samples from Saldanha ay (33°S, 18°E) were analysed by both methods. esults are shown in Table IV, from which the nclusion is drawn that the Jirka and Carter 975) method does not compare with Michel's 972) method for measuring the COD of seawater m unpolluted areas, although it could be used r measuring the COD of the actual pollutant at urce. In fact, Jirka and Carter's *(op. cit.)* method used regularly for this purpose by Water Authorities in the United Kingdom (Best and De Casseres 1978).

able IV: A comparison of the COD of some natural samples estimated by two different methods (samples taken from Saldanha Bay)

Sample	COD found (ppm)	
	Michel (1972)	Jirka and Carter (1975)
1	11	102
2	11	292
3	14	181
4	36	292
5	15	212
6	10	212
7	47	212

CONCLUSIONS

Results from these studies show clearly that the method of Jirka and Carter (1975) cannot be used, even with dilution, for natural seawater samples, although it might be used for the analysis of a particular input. If, however, the total chemical oxygen demand is required, then the method of Michel (1972) appears the better at present. This method does, however, suffer from requiring large quantities of expensive reagents, and the use of large quantities of concentrated sulphuric acid together with mercury salts could well pose a health and pollution hazard.

Whether total chemical oxygen demand is, in fact, a useful parameter is, however, another matter. It would seem that the important thing to measure is the easily oxidizable carbon content, since it is this portion of an effluent that accounts for the oxygen demand in the natural environment, and hot concentrated sulphuric acid would appear to be a rather drastic treatment for this.

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1980

INVESTIGATIONS INTO METHODS OF DETERMINING ORGANIC POLLUTION IN SEAWATER. 2. A COMPARISON OF TWO METHODS FOR THE DETERMINATION OF "OXYGEN ABSORBED"

P. CHAPMAN

Two methods of determining the extent of organic pollution by means of permanganate oxidation in both acid and alkaline conditions are compared. Both are affected to an equal extent by concentration of dissolved chloride. The acid method was found to give more reproducible results. Discrepancies between values for the same effluent analysed by both methods are discussed in terms of the chemical make-up of the effluent.

Twee metodes vir die bepaling van die mate van organiese besoedeling deur die oksidering van permanganaat in suur sowel as alkaliese toestande word vergelyk. Albei word in gelyke mate deur opgeloste chloried-konsentrasie geaffekteer. Daar is bevind dat die suurmetode reproduseerbaarder resultate oplewer. Verskille tussen waardes vir dieselfde uitvloeisel wat volgens albei metodes ontleed is, word bespreek na aanleiding van die chemiese samestelling van die uitvloeisel.

An estimate of the amount of organic material in a sample is often of importance in determining the effects of industrial effluents on the environment. This is particularly true when such a discharge is liable to lead to a pollution problem, as is the case with, for example, the effluent discharged from fish factories. Although the particulate organic carbon content of such effluents may be measured relatively easily (Strickland and Parsons 1972), they also contain large quantities of blood and other dissolved materials which have a drastic effect on oxygen concentration but which are not accounted for by this method.

Chemical methods for the measurement of oxygen demand are well known in the water industry, but the standard test for chemical oxygen demand cannot be used successfully in seawater because of simultaneous chloride oxidation. It is also difficult to use a C:H:N analyser, even when modified to take automatic samples (van Steenderen 1976), because the salt clogs the burner and reduces the efficiency of the catalyst in the burner tube. It is possible, however, to measure the oxygen demand by means of the reduction of permanganate. This method is commonly referred to as "Oxygen Absorbed" (OA) to distinguish it from other methods. Two standard methods for the procedure are known, utilizing acid (South African Department of Water Affairs 1969) or alkaline (A.P.H.A. and A.W.W.A. 1946) conditions respectively, both being considered to give a fair measurement of the oxygen absorbed.

The former method has been used routinely by the Sea Fisheries Institute, while the alkaline method has been used by the National Institute for Water Research, Durban, and the National Research Institute for Oceanology. In view of the attempts by the South African Marine Pollution Monitoring Panel to provide a standardized methods list for laboratories engaged in marine pollution monitoring, a comparison between the two methods is desirable to determine which is the more accurate and simpler to use, and to compare the results of different analyses.

SAMPLING

Water samples (2,5 ℓ) were taken (in acid-washed bottles) on the same day from the following four localities in or near Cape Town:

(i) Table Bay Docks,
(ii) Oudekraal,
(iii) Hout Bay — near the effluent stream of a fish-processing factory,
(iv) Hout Bay — from the effluent stream.

Hout Bay and Oudekraal are both located on the west coast of the Cape Peninsula, Hout Bay about 11 miles south of Cape Town and Oudekraal about 6 miles south.

Table Bay was considered to be an example of an area polluted by general industry, whereas Hout Bay was considered to represent an organically polluted area. Oudekraal was regarded as a "clean" area.

Samples were not filtered, because both dissolved and particulate fractions were thought to contribute to the oxygen demand, nor frozen, because they were analysed by the acid digestion method on the day following collection, and by the alkaline method one day later.

METHODS

Detailed descriptions of the acid and alkaline methods are given in South African Department of Water Affairs (1969), and A.P.H.A. and A.W.W.A. (1946) respectively. Briefly, the acid method consists of digesting the sample (100 mℓ) in a water bath with 10 mℓ of 25-per-cent sulphuric acid and 20 mℓ of potassium permanganate (0,40 g.ℓ$^{-1}$) at 27°C for four hours in the dark. After digestion, potassium iodide is added and the liberated iodine titrated with standard thiosulphate.

In the alkaline method, the sample (100 mℓ) is made alkaline with 0,5 mℓ of 33-per-cent sodium hydroxide and digested with 10 mℓ of permanganate (0,40 g.ℓ$^{-1}$) on a boiling water bath for 30 minutes. An amount of 25 ml of a solution of manganous sulphate (made up with 67 g $MnSO_4$.$4H_2O$, 138 mℓ 85-per-cent phosphoric acid, 130 ml concentrated sulphuric acid and distilled water to 1 litre) is then added, and the solution titrated with standard ferrous ammonium sulphate.

Five aliquots of each sample were analysed simultaneously with three blank determinations. The first test on the samples was made on the two days after collection and the same samples were reanalysed two weeks later, also on consecutive days. Volumes of samples were chosen so as to ensure that sufficient permanganate was present in solution, where necessary diluting a smaller volume to 100 mℓ.

Initially a problem was experienced with the determination of the end point in the alkaline method. According to Vogel (1951), diphenylbenzidine is a suitable indicator for the reaction between permanganate and ferrous ammonium sulphate, but it was found that under the conditions used in this test the indicator was very slow to change colour at the end point and that considerable overshooting occurred. This problem was finally resolved by using a "dead-stop" titrator and plotting the volume of titrant added against the measured current.

RESULTS AND DISCUSSION

The results of the two sets of analyses made two weeks apart are shown in Table I, together with means and standard deviations. Analysis of variance showed that the differences between the five pairs of determinations were statistically significant. The variation between the two sets analysed by the same method was not considered important since it was likely that changes would occur in the easily degraded organic component, either from the degradation of the initially resistant portion or from the consumption of previously labile compounds by bacteria. The second series of measurements could thus be considered as a second set of samples. It was noticeable, however, that an increase or decrease in the mean of a set of samples measured by the acid method was mirrored by a similar increase or decrease in the samples analysed by the alkaline method. The exception was the effluent sample, in which the mean from alkaline oxidation increased whereas that from acid oxidation remained virtually constant.

The differences between the means are, however, more important since it was hoped that the analyses would correlate well, allowing the results already obtained over several years to be directly compared. If anything, it was expected that the results obtained by acid digestion would be higher than those obtained by alkaline digestion, since Vogel (1951) states that the addition of Mn(II) lowers the oxidation potential of the permanganate and renders it less liable to oxidize chloride ions. As can be seen from Table I, however, this does not appear to be so, and in all cases the results from analysis by the alkaline method are higher than those from the acid procedure. It was not clear whether this discrepancy was the result of the effect of chloride in solution or of the difference in the physical conditions of the analysis (a boiling water bath seeming rather more drastic treatment even if the time scale is shorter).

The effect of sodium chloride was therefore tested by analysing five subsamples of a 0,5 M solution of NaCl in distilled water by both methods and comparing them with a distilled-water blank. The results in Table II show that the difference between the two methods is statistically insignificant.

Similarly, the effect of temperature on the reaction was determined by analysing a further set of samples of the Hout Bay water by both methods, but by keeping each at a temperature of 27 °C for four hours in the dark. The results of this test are shown in Table III. The difference between the two sets of subsamples is marked, and therefore the physical conditions of the test are as important as the chemistry in the oxidation of organic matter by permanganate.

The reproducibility of each method is shown in Table I. The standard deviations of each set of samples prove that the acidic method is subject to

Table I: Results of the analysis of four samples done twice by two different methods (all values in mg.ℓ^{-1})

Sample	First analysis		Second analysis	
	Acid method	Alkaline method	Acid method	Alkaline method
Table Bay Docks	1,073	1,758	0,936	1,516
	1,060	1,530	0,796	1,689
	1,066	2,024	0,774	1,372
	0,959	1,112	0,682	1,112
	1,100	—	0,774	0,809
Mean	1,052**	1,606	0,792*	1,300
Standard deviation	0,054	0,386	0,092	0,346
Oudekraal	0,885	3,772	0,566	2,072
	0,892	1,112	0,612	0,808
	0,832	1,510	0,683	0,794
	0,859	2,080	0,636	0,635
	0,832	2,270	0,844	0,462
Mean	0,860*	2,149	0,668	0,954
Standard deviation	0,028	1,017	0,107	0,640
Hout Bay — near fish factory	4,146	4,769	5,140	4,274
	4,052	5,662	5,186	6,570
	4,146	5,548	5,118	6,209
	4,226	4,161	5,140	3,928
	4,078	4,807	5,094	7,076
Mean	4,130*	4,989	5,136	5,611
Standard deviation	0,068	0,619	0,034	1,418
Hout Bay — effluent	11,618	41,325	12,544	60,359
	11,685	45,220	12,220	69,890
	11,786	45,315	11,296	63,536
	11,685	41,515	11,528	63,536
	11,752	43,605	10,372	63,536
Mean	11,705**	43,396	11,592**	64,171
Standard deviation	0,066	1,929	0,849	3,480

* Differences significant at 95% level
** Differences significant at 99% level

far less variation than the alkaline method. There is no obvious reason for this discrepancy, since titration in both acid and alkaline media is used routinely by analysts for the determination of permanganate. It may well be that the different media promote the breakdown of different classes of

Table II: The OA value of a 0,5 M NaCl solution compared with distilled water

Subsample	Apparent OA (mg.ℓ^{-1})	
	Acid method	Alkaline method
1	0,425	0,295
2	0,441	0,295
3	0,346	0,410
4	0,425	0,389
5	0,472	0,305
Mean	0,422	0,339
Standard deviation	0,047	0,056

Table III: The effect of treating samples analysed by both methods at 27 °C for four hours

Subsample	Apparent OA (mg.ℓ^{-1})	
	Acid method	Alkaline method
1	6,016	0,631
2	5,890	1,915
3	5,732	0,673
4	6,142	0,526
5	5,732	0,884
Mean	5,902	0,926
Standard deviation	0,179	0,568

organic compounds. Fish-factory effluents are noted for their high oil content, which is generally more easily saponified in alkaline conditions, and this may account for the variation in the results from the effluent sample, where difference factors of 4 and 6 between the two sets of values were obtained.

The interpretation of OA results requires some care. From analyses over a period of years in Saldanha Bay (Sea Fisheries Institute, unpublished data) it would seem that an area can be considered "clean" if the OA value is less than 1 mg. ℓ^{-1}. Between 1 and 2,5 mg. ℓ^{-1} there is some contamination, but these levels do not appear to damage the environment. Anything above this level would appear to stem from a "polluted" environment, and values of 10 mg.ℓ^{-1} or higher would appear to to denote severe pollution.

Although the two tests give results that differ significantly when subjected to statistical analysis, the importance of the difference is open to speculation. The values in Table I suggest that Oudekraal and Table Bay are both "clean" organically, whereas Hout Bay is polluted by fish-factory effluent. For a monitoring method, where only the main areas of pollution need to be determined after which more quantitative work can be done by, for example, the analysis of particulate organic carbon or infra-red or gas-liquid chromatograph studies, the "oxygen absorbed" method would appear to be adequate. While it is disappointing that the two methods do not give identical results, on a qualitative basis the agreement appears reasonable.

CONCLUSIONS

The discrepancies found between the results of the two methods are probably the result of the different physical conditions employed in the tests, and of the action of the permanganate reagent on different classes of organic compounds. Although neither method can be said to give an absolute measurement of the amount of organic matter in a sample, the OA figures obtained may be used qualitatively as a guide to whether or not an area is polluted and, if so, how seriously. In this context it is as well to remember that both tests measure only "easily" oxidized organic matter, which is the fraction most affecting the oxygen supply and thus determining the degree of pollution. They appear to be of little use in establishing the total oxygen demand of an effluent if it consists of compounds highly resistant to degradation.

Both methods were found to be equally affected by the dissolved chloride in seawater, and the only advantage in preferring the method of acid digestion is that it is much more reproducible. Further studies on the various constituents of common effluents round South Africa are continuing.

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QUANTITATIVE STOCK SURVEY AND SOME BIOLOGICAL AND MORPHOMETRIC CHARACTERISTICS OF THE DEEP-SEA RED CRAB *GERYON QUINQUEDENS* OFF SOUTH WEST AFRICA

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In order to assess the abundance of the red crab *Geryon quinquedens*, two otter-trawl cruises were undertaken, in July and September 1978, on the continental slope off South West Africa. A bimodal frequency distribution of female crabs was evident with modal sizes at 7,7 cm and 8,7 cm carapace width, whereas the mode for males was at 11,2 cm. In general, larger animals tended to inhabit shallower water, i.e. size is inversely related to depth. Females preferred shallower water than males. Shell states indicated that males were predominantly in the inter-moult stage while most females were either approaching or had recently completed the moult. From morphometric relationships, it was calculated that, in processing the live material to a cooked frozen product, red crab is subject to a mass loss of about 54 per cent. Analysis of stomach contents by volume showed that only 12 per cent of male stomachs contained 5 per cent or more food and 2 per cent of female stomachs exceeded the 5-per-cent level. Highest crab densities occurred at depths of 472-849 m, whereas unusually high concentrations were encountered during two trawls at water depths of 549 and 590 m. The red crab survives at extremely low levels of dissolved oxygen and tolerates a temperature range of more than 7°C.

Tydens Julie en September 1978 is twee otter-treilvaarte onderneem op die kontinentale helling langs die kus van Suidwes-Afrika om die talrykheid van die rooikrap *Geryon quinquedens* vas te stel. Wyfies het twee lengtemodi by karapakswydtes van 7,7 cm en 8,7 cm onderskeidelik getoon terwyl die lengtemodus vir mannetjies op 11,2 cm te staan gekom het. In die algemeen het dit geblyk dat die groter krappe in vlakker water voorkom, nl. dat grootte omgekeerd eweredig aan diepte was. Die doptoestand van mannetjies het getoon dat die diere in die tussen-verdoppingstadium was terwyl wyfies òf verdopping genader het òf reeds verdop het. Van morfometriese verhoudings is afgelei dat 'n massaverlies van ongeveer 54 persent intree van die lewende krap tot by die verwerkte eindproduk aan boord. Pensinhoudvolumes het getoon dat net 12 persent mannetjies 5 persent of meer voedsel bevat het en 2 persent wyfies die 5 persentpeil oorskry het. Die hoogste krapdigthede het op dieptes van 472—849 m voorgekom maar ongewoon hoë digthede is op dieptes van 549 m en 590 m aangetref. Die rooikrap leef by uiters lae suurstofwaardes en die diere kan 'n temperatuurspeling van meer as 7 °C weerstaan.

The red crab *Geryon quinquedens* (Fig. 1) is known and exploited in many parts of the world. Off Africa, it is known to occur in commercially exploitable quantities off the Ivory coast, the Congo, Angola and South West Africa along the west coast, and also off northern Natal and Mozambique along the east coast.

Commercial exploitation off South West Africa started in 1973 when three Japanese trap vessels caught 3 877 metric tons whole mass. Fishing effort increased in 1974, when seventeen Japanese vessels and one mother vessel of 1 500 gross tons exploited this valuable resource. In ensuing years, however, efforts decreased owing to marketing problems, and by 1979 only five vessels were operating. A company based in South West Africa entered the fishery in 1976, but its vessel ran aground towards the end of that year. Two replacement vessels of 611 and 579 tons restarted fishing operations in November 1977.

The catch from the South West African vessels, as well as purchases from the Japanese, is processed at a land-based factory in Lüderitz. The processed product is predominantly exported to America, France, Britain, Holland and Belgium.

Beehive-type traps (Fig. 2), up to 600 on a longline, are used in fishing, each vessel carrying up to 1 200 traps. The traps are 60 cm high, 78 cm in diameter at the top and 136 cm in diameter at the bottom. A conical plastic collar serves as an entrance at the top of the trap and is 60 cm in diameter. At present, no legal minimum size limit, closed season or quota limitation exists for the species, but only animals larger than 11,0 cm in carapace width are retained on board the South West African vessels. Animals of suitable size are "sectioned" (carapace and viscera removed), cooked and blast frozen to −20°C before being further processed ashore.

Because of the increasing interest in the red-crab fishery, two quantitative surveys were conducted on the continental slope off the South West African coast in July and September 1978. The area surveyed extended from 19° 16,4′S to 20°00′S and from 11° 15,5′E to 11°58,5′E. Water depths of 295-849 m were covered. Primary purposes

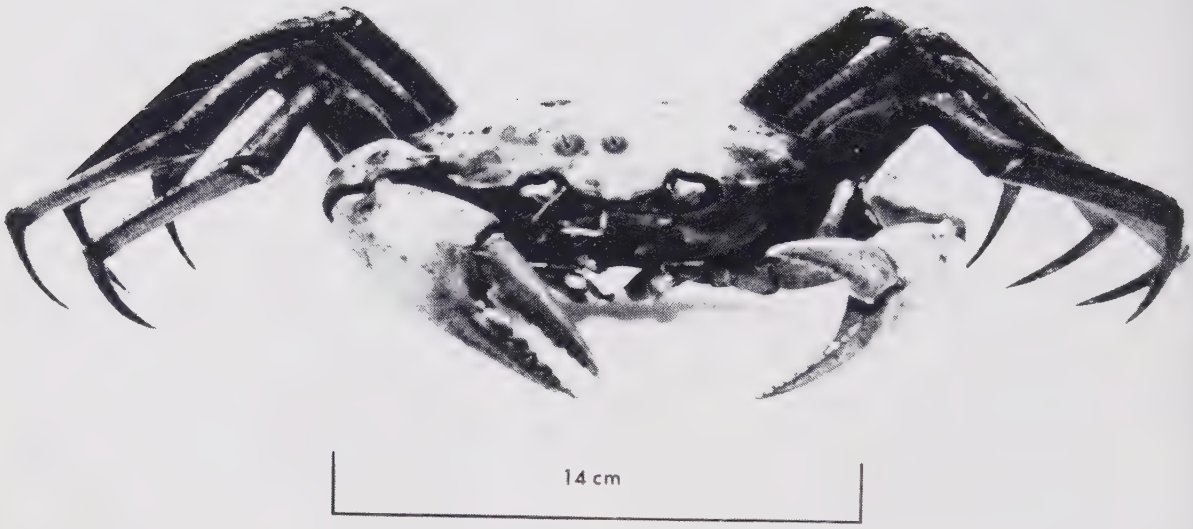

Fig. 1: The red crab *Geryon quinquedens*

of the surveys were to determine the distribution and to estimate the relative abundance of crabs in the area. Secondary objectives were to assess the size composition of the species and to obtain information on its biological cycles and ecology.

MATERIALS AND METHODS

Surveys were conducted from R.S. *Benguela* (July) and R.S. *Africana II* (September). Sampling gear consisted of a standard otter trawl with a foot-rope length of 47 m and an approximate effective sampling width of 25 m. No herding of crabs by the sweeps of the trawl was suspected, and therefore 25 m was considered a more realistic sampling width than the distance between the doors (100 m). The codend of the net was lined with 27,5-mm mesh pilchard netting at all times to ensure that juvenile crabs and other small animals could not escape through its 75-mm mesh. A total of 57 trawl stations was completed during the two surveys (Fig. 3). The net was towed at 2-2½ knots for a period of one hour at each station. The distance of each trawl was calculated, assuming that trawling took place in a straight line, by applying trigonometry to the known latitude and longitude positions of blocking up and knocking out of the trawl.

Trawl contents were sorted into species, except for sharks and skates which were grouped, and where possible counted. Rough estimates of numbers or mass were made for abundant species only. Where identification of species was difficult, samples were frozen and returned to the laboratory.

Bottom water samples were taken twice a day by means of a Munro-Ekman bottle. The temperature at the depth of sampling was determined by means of reversing thermometers and all samples

Fig. 2: Typical beehive-type trap used for crab-fishing off South West Africa

were analysed for dissolved oxygen (on board) and salinity (ashore). The Munro-Ekman bottles were fitted with protected and unprotected thermometers, thus enabling the calculation of the true sampling depth.

Dissolved oxygen values were determined by the Winkler method during the September survey and by means of an oxygen probe during the July survey. It was shown by Hart and Currie (1960) that the presence of organic matter, quantities of nitrite of 0,71μg at.N/ℓ and over, and sulphate-reducing bacteria can affect the Winkler estimation. No allowance was made for interference in the Winkler method by these contaminants because it was thought that the results would only be slightly affected.

All red crabs caught were measured (for size frequency distribution) and sexed, and their state of shell was determined. Size was expressed as carapace width and was measured between the fifth anterolateral teeth or denticles. The carapace width was determined by means of calipers to the nearest millimetre. No mass (weight) determinations were made at sea, but on return to the laboratory, the carapace width of individual animals was again measured and the mass at each stage of processing determined to the nearest gramme. The presence or absence of ovigerous setae in females was taken as an indication of sexual maturity. The state of the exoskeleton was divided into five categories:

(i) hard (H), when the carapace is of maximal strength and in the inter-moult stage;
(ii) hard old (HO), when the animal is approaching moulting and the newly formed exoskeleton can be detected within by breaking an antenna;
(iii) soft old (SO), when the resorptive line along

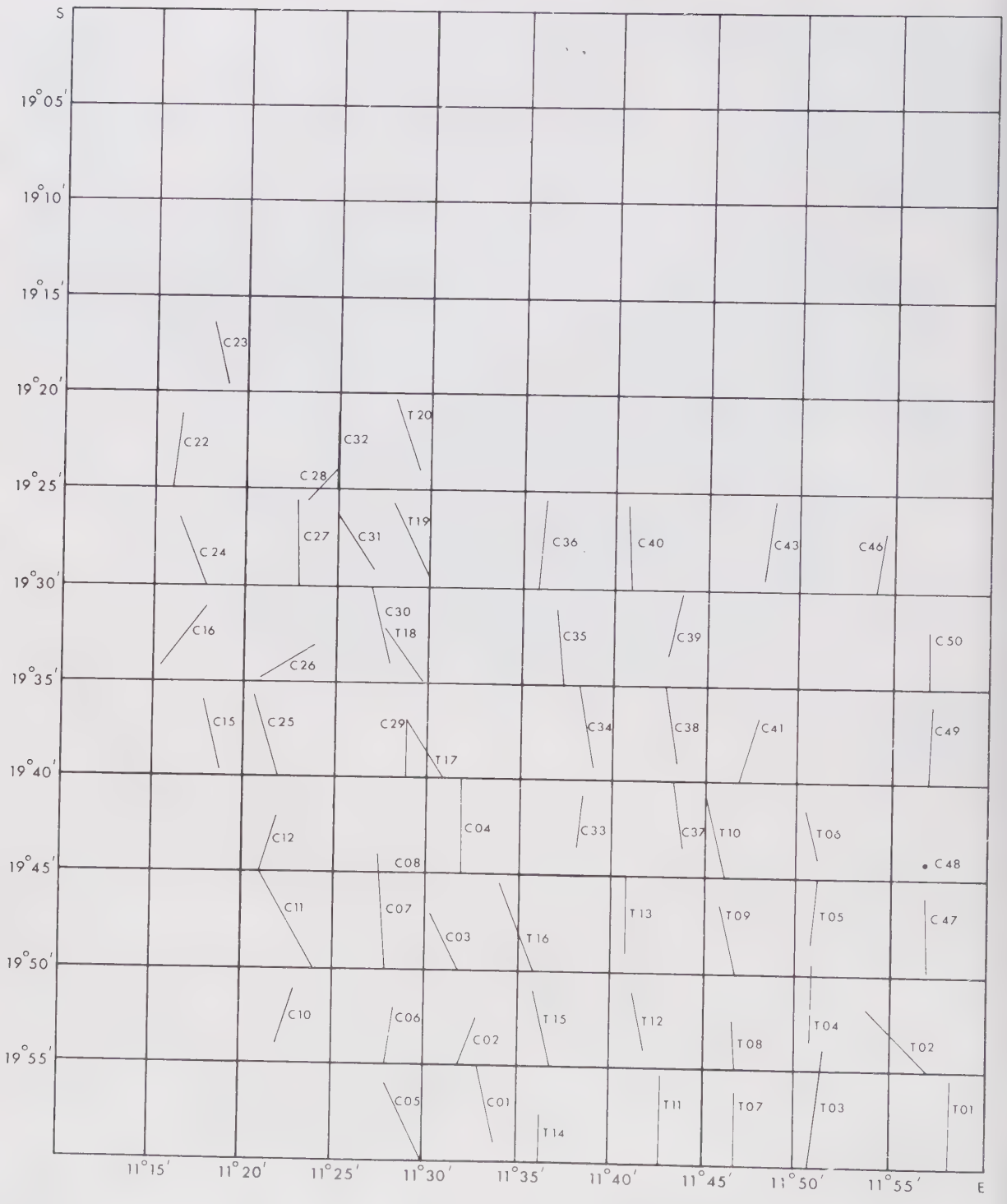

Fig. 3: Positions of trawl stations, July and September 1978

the lateral sides of the carapace is soft to the touch and the animal is in the immediate premoult stage;

iv) soft new (SN), when the carapace is soft or jelly-like and in the immediate post-moult stage;

(v) hard new (HN), when the lateral sides of the carapace yield and crack under slight pressure and the animal is approaching the inter-moult stage.

Relationships between carapace width and total body mass (wet mass), section mass (wet mass, not frozen), section mass (cooked not frozen) and section mass (cooked and frozen) were made for males and females. These measurements are necessary for converting production figures (ex factory) to landed mass of the catch.

RESULTS

Population characteristics

Data for both surveys were combined to portray the size-frequency distribution by 5-mm carapace-width class over the entire depth range surveyed (Fig. 4). A bimodal frequency distribution of females is evident with modal sizes at 7,7 cm and 8,7 cm carapace width. The size distribution for males is normal with the mode at 11,2 cm. Mean sizes of 11,1 cm and 8,0 cm were calculated for males and females respectively, and males made up 64 per cent of the total population.

Evidence of variations in size with depth has been recorded for *Geryon quinquedens* off the north-eastern United States by Wigley *et al.* (1975), off the Ivory coast by Intes and Le Loeuff (1976) and off the Angolan coast by Dias and Machado (1973). Each of these authors found that young crabs predominated in deeper water and that large crabs were only caught in shallow water. In order to determine whether a similar depth stratification existed in South West African waters, the size-frequency distributions were further analysed separately for each 100-m depth range. The mean size of animals and the sex ratios in each of the depth ranges were calculated and are summarized in Table I.

The results in Table I indicate that the mean size of male crabs decreases with increase in depth except deeper than 800 m, where a small increase in size was found. Similarly, females also decrease in size with increase in depth up to 600 m deep, but thereafter the size remains relatively consistent. In general, it would seem that, as found for the same species in other parts of the world, larger animals tend to inhabit shallower water and that size is therefore inversely related to depth.

Dias and Machado (1973) and Intes and Le Loeuff (1976) showed that a definite segregation of the sexes in *Geryon quinquedens* occurs along the Angolan and Ivory coasts respectively. They found that females were dominant in trap catches at depths of 300-450 m. A 1:1 sex ratio was found at approximately 450 m, whereafter male animals became dominant. At 600 m and deeper no females were encountered.

In the present survey a similar trend in sex ratios was observed. Females were caught in equal numbers up to 400 m deep, but in deeper water they became progressively scarcer. In water 600-700 m deep, males outnumbered females by 2:1, at 700-800 m by 4:1 and deeper than 800 m only 2,5 per cent of the catch was female.

Generally, it would seem, therefore, that female animals prefer shallower waters than males.

Moulting

Information on moulting and berry cycles of

Table I: Mean carapace width and sex ratio of red crab caught in each depth range.

Depth (m)	Mean carapace width (cm)			Sex ratio (%)	Sample size
	Males	Females	Both sexes	Males : Females	
< 400	12,3	8,7	10,4	47,5 : 52,5	139
401 – 500	12,1	8,1	10,2	53,5 : 46,5	505
501 – 600	11,5	7,9	20,0	56,1 : 43,9	1 201
601 – 700	11,2	7,9	10,2	67,4 : 32,6	282
701 – 800	10,1	8,1	9,7	80,8 : 19,2	546
> 800	10,4	7,9	10,4	97,5 : 2,5	160

Table II: Shell states of both sexes during each survey

Month	Shell state (numbers)					
	Males			Females		
	H	HO + SO	SN + HN	H	HO + SO	SN + HN
July	604	—	33	269	100	164
September	1 158	—	—	180	131	188
July + September	1 762	—	33	449	231	352
Percentage	98,2	—	1,8	43,5	22,4	34,1

Geryon quinquedens is limited, but it would seem that the two surveys conducted during July and September coincided with the female moulting period.

Shell states were grouped into inter-moult (H), premoult (HO + SO) and postmoult (SN + HN) stages. The results for both surveys are presented in Table II.

From Table II it may be seen that male animals were predominantly in the inter-moult stage. However, less than half the females were in the same stage and these were assumed either to have hardened after the moult or to be approaching the moult period. From the available data, it is suggested that females moulted during the survey period (July-September), but it is possible that moulting actually extends over a much wider period.

Only one female was found to be in berry during July. Also, although 50 per cent of females caught during July were either in the immediate premoult or postmoult stages (Table II), again only one female was in berry in September and 64 per cent were still found to be in these stages close to moulting. If it is assumed that mating occurs while females are in the SN shell stage, it would be reasonable to conclude that the available data substantiate the findings of Haeffner (1977), who stated that spawning of *Geryon* can occur well after mating. It is possible that the main female berry season may only start in October, but this assumption depends largely on determining the time-lapse involved between mating and egg appearance.

Sexual maturity

The presence of ovigerous females was taken to be an indication of sexual maturity. During the two surveys a total of 1 023 female animals between 6,2 and 10,2 cm carapace width was examined and all were ovigerous. It appears, therefore, that females become sexually mature before attaining 6,2 cm carapace width.

Morphometrics

Catch statistics forms were completed by the two South West African vessels. Information supplied includes catch positions, the number of traps utilized on each longline, the duration of each set, the number of days spent fishing, the frozen cooked mass caught per longline and the duration of the trip. To assist in the analysis of these data, various morphometric relationships of the form $y = ax^b$ (where x is the carapace width in centimetre and y is the mass in gramme) were calculated.

Up to five animals in each 0,5-cm size class were taken and males and females were analysed separately because the bulk of commercial catches consists of males (Fig. 4). Only animals in the inter-moult hard-shell state and which had lost no appendages were used in the analysis. Totals of 138 males between 6,5 and 16,4 cm carapace width and 58 females between 6,0 and 10,4 cm were used.

Carapace width: whole mass (wet mass) — After thawing in the laboratory, the whole mass measurements were made. The equations were:

Males $y = 0{,}1909\ x^{3{,}1948}$
Females $y = 0{,}5234\ x^{2{,}7018}$
where y = whole mass.

Carapace width: section mass (wet mass) — After whole mass measurements had been made, the animals were sectioned in the same manner as on the commercial vessels. Sections were weighed and the relationship calculated as:

Males $y = 0{,}0873\ x^{3{,}3294}$
Females $y = 0{,}3786\ x^{2{,}5829}$
where y = section mass.

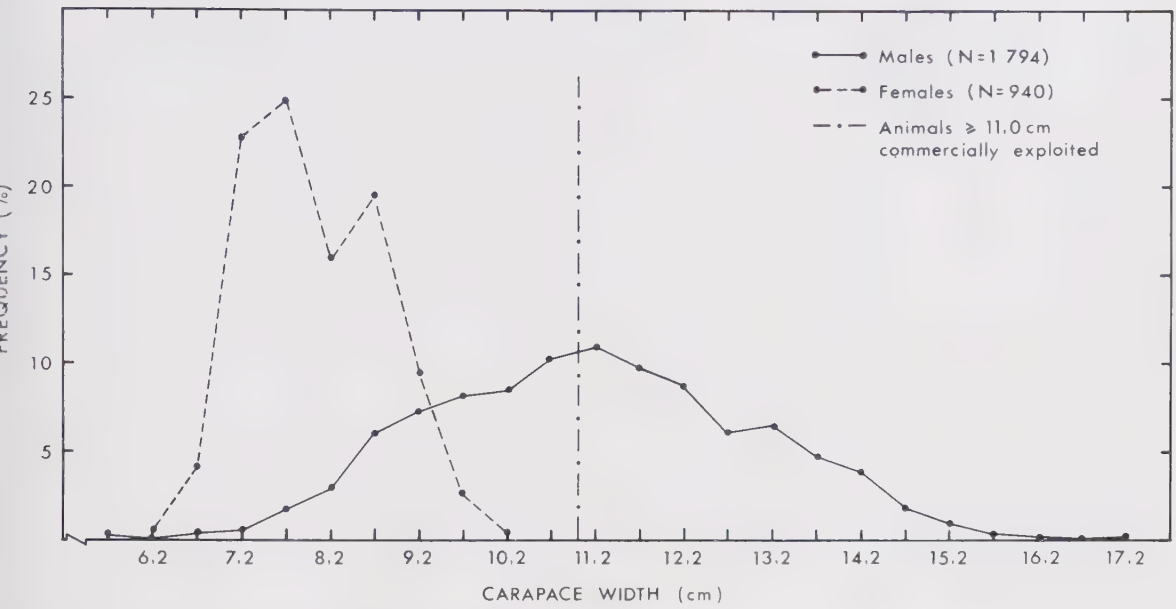

Fig. 4: Size composition of red crab off South West Africa in water 302—849 m deep (results from both cruises combined)

'arapace width: section mass (wet, cooked mass) – Immediately following wet mass determination, ne raw sections were placed in boiling seawater or nine minutes (as they are treated on commercial essels). Residual water was drained from the ections before weighing and the relationships ere calculated as:

ales $y = 0{,}0848\ x^{3{,}2873}$
emales $y = 0{,}5949\ x^{2{,}3037}$
here y = cooked section mass.

arapace width: section mass (cooked, frozen) — he cooked sections were frozen overnight and gain weighed the following morning. The equations ere calculated to be:

ales $y = 0{,}0883\ x^{3{,}2573}$
emales $y = 0{,}6486\ x^{2{,}2513}$
here y = frozen, cooked section mass.

It was calculated that the wet section mass onstitutes 60,3-65,8 per cent of the wet total ody mass for male animals in the size range 6,5-6,4 cm and 54,4-57,4 per cent for females in the ,0-10,4 cm size range.

After sections had been cooked, mass losses of 0,5-13,3 per cent for males and 8,8-19,6 per cent or females were noted. Freezing of these sections esulted in a further mass loss of 3,7-4,0 per cent for males and 1,5-3,8 per cent for females.

Section mass constitutes approximately 63,0 per cent of the whole mass of commercially exploited animals (i.e. predominantly male animals with a mean carapace width of 11,2 cm). The product off-loaded at the land-based factory would have suffered a further 9-per-cent mass loss during cooking and freezing and would therefore constitute about 54 per cent of the initial whole mass.

Stomach contents

Stomach contents of 159 males and 56 females in the 6,5-16,4 cm and 6,0-10,4 cm size ranges respectively were analysed in an attempt to determine feeding preferences of *Geryon quinquedens*. The species has powerful chelipeds, and it was therefore expected that some type of hard-shelled organism would constitute a major part of the diet.

Overall, 51,6 per cent and 89,3 per cent of male and female stomachs respectively were empty. Care was taken to sample stomachs from animals in a hard-shelled state, thus ensuring that only animals capable of active feeding were analysed. The degree of repletion was estimated as a percentage of the total stomach volume, and it

Table III: Crab density in order of increasing depth, July and September 1978 surveys combined

Station number	Station depth (m)	Distance trawled (km)	Area trawled (km^2)	Number caught	Density (number/ha)
C46	295	4,8	0,1208	0	—
C50	302	4,8	0,1208	0	—
C49	310	6,8	0,1691	0	—
C43	313	6,4	0,1610	0	—
T01	324	8,1	0,2013	1	1,0
C39	332	5,3	0,1329	0	—
C47	339	6,3	0,1570	1	1,0
T02	343	6,3	0,1570	1	1,0
C40	347	7,1	0,1771	2	1,0
C38	347	6,4	0,1610	0	—
T06	351	4,2	0,1047	0	—
C41	354	5,6	0,1409	0	—
C37	369	5,5	0,1369	13	1,0
T05	370	5,6	0,1409	8	1,0
C35	376	6,4	0,1610	21	1,3
T10	380	7,1	0,1771	10	1,0
C36	384	7,4	0,1852	26	1,4
C34	384	7,7	0,1932	0	—
T04	388	6,4	0,1610	37	2,3
T09	395	5,8	0,1449	19	1,3
T08	402	4,0	0,1006	32	3,2
T03	410	9,7	0,2415	21	1,0
C33	428	4,7	0,1167	38	3,3
T13	435	6,4	0,1610	37	2,3
T07	439	6,1	0,1530	35	2,3
T20	457	6,3	0,1570	58	3,7
T12	472	5,2	0,1288	82	6,4
T11	479	7,4	0,1852	96	5,2
T19	483	6,8	0,1691	107	6,3
T18	520	5,5	0,1369	117	8,6
C30	524	7,1	0,1771	54	3,1
C31	524	6,4	0,1610	89	5,5
C32	531	6,4	0,1610	89	5,5
T16	534	7,9	0,1973	95	4,8
C29	540	4,8	0,1208	57	4,7
T17	540	5,8	0,1449	49	3,4
T14	549	4,0	0,1006	231	23,0
T15	556	6,6	0,1651	139	8,4
C04	576	8,1	0,2013	53	2,6
C27	583	7,2	0,1812	108	6,0
C28	590	3,4	0,0845	120	14,2
C03	638	5,5	0,1369	48	3,5
C02	646	4,3	0,1087	32	2,9
C26	649	5,5	0,1369	45	3,3
C23	664	5,3	0,1329	99	7,5
C07	664	9,8	0,2456	35	1,4
C01	666	6,3	0,1570	23	1,5
C06	701	5,5	0,1369	23	1,7
C25	701	7,1	0,1771	86	4,9
C22	708	6,4	0,1610	37	2,3
C21	738	5,6	0,1409	85	6,0
C05	756	7,2	0,1812	15	0,8
C16	768	5,8	0,1449	113	7,8
C11	790	9,3	0,2335	117	5,0
C15	797	6,0	0,1490	70	4,7
C10	834	5,6	0,1409	64	4,5
C12	849	5,2	0,1288	96	7,5

was found that only 12 per cent of male stomachs contained 5 per cent or more food while 2 per cent of female stomachs exceeded the 5-per-cent level of repletion.

Small shell fragments (probably from goose barnacles), fish scales and bones of small fish,

emains of small crustaceans and unidentifiable igested food were the major constituents of the tomachs analysed.

The only conclusion that can be drawn from tomach-content analysis is that ingestion of food akes place at an extremely slow rate, possibly as result of the limited availability of food. This ossibility may be investigated at a later stage by redging or by a photographic survey.

CRAB DENSITY

Crab densities were determined for each trawl n both surveys and are presented in Table III. The sampling width of the otter trawl (25 m) and he distance trawled at each station were used to letermine the area sampled and, from this, relative lensities were expressed as number of animals er hectare.

Wigley *et al.* (1975), in a similar survey off the orth-eastern United States, found the biomass ndex for *Geryon* to be high at depths of 320-03 m, lower in shallower and deeper waters and ero at depths of 1 280-1 646 m.

During the present surveys, less than one animal er hectare was encountered at depths of 295-80 m off South West Africa. Higher densities ≥4/ha) occurred at depths of 472-849 m and nusually high densities were encountered during wo trawls at water depths of 549 and 590 m where alues of 23/ha and 14/ha respectively were calcu-ated.

Wigley *et al.* (1975) summarized results from a ,9-m balloon otter trawl as catch rate by depth ange for each 30-minute haul. Results of the resent surveys, where a 47-m otter trawl was sed for a 60-minute haul, are compared to those btained by Wigley *et al.* (*op. cit.*) in Table IV.

The highest catch rate off the United States ccurred at depths of 320-503 m whereas the ighest off South West Africa was found at depths f 412-849 m. These differences in catch rate with epth from two widely separated geographical egions may be attributed to, for example, bottom opography, availability of food, environmental onditions and differing catching techniques.

Intes (1976) surveyed the fishing grounds off he Ivory Coast by means of traps and found the ighest catch per unit effort (C.P.U.E.) at a depth f 400 m, a lower value at 300 m and lower still at 00 m.

Dias and Machado (1973) documented C.P.U.E. lata off the Angolan Coast, based on traps of

Table IV: Comparison of catch rate of *Geryon quinquedens* off South West Africa and in the north-eastern United States

Depth (m)	Catch rate	
	Wigley *et al.* (per 30 minutes)	Present surveys (per hour)
229–320	1–14	0
321–412	14–218	0– 37
413–503	21–128	35–107
>503	2–40*	15–231†

* Maximum depth sampled 1 280 m

† Maximum depth sampled 849 m

different dimensions and shape from those used by Intes (1976). Bait and immersion times also differed. The highest C.P.U.E. was in depths of 400-800 m along the southern section of the coast but, in contrast, the C.P.U.E. was very low in the same depths along the northern section of the coast.

To conclude, it would appear that densities of *Geryon* can vary greatly with locality and depth for reasons that are at present unknown.

DISTRIBUTION AND HYDROLOGY

Bottom water samples were taken twice daily, before trawling commenced in the morning and after completion of the last station in the late afternoon. Bottom dissolved oxygen, salinity and temperature values were monitored.

Results obtained during the July survey were similar to those during September but, because different methods were applied in determining the dissolved oxygen, only the data from the September survey are presented in Table V. Extremely low dissolved oxygen values were recorded in the shallower water (295-428 m), all being less than 1,0 mℓ / ℓ. Somewhat higher values were recorded in deeper water with a maximum of 2,98 mℓ / ℓ at 797 m.

Bottom temperature ranged from 11,24°C at 295 m to 4,56°C at 834 m and a general trend of decrease in bottom temperature with increase in depth was evident. Bottom salinity ranged from 34,35 to 34,99 ‰ and its general trend was also that of decrease with increasing depth.

As most brachyurans are euryhaline, it would appear that dissolved oxygen concentration, temperature and depth are the main hydrological

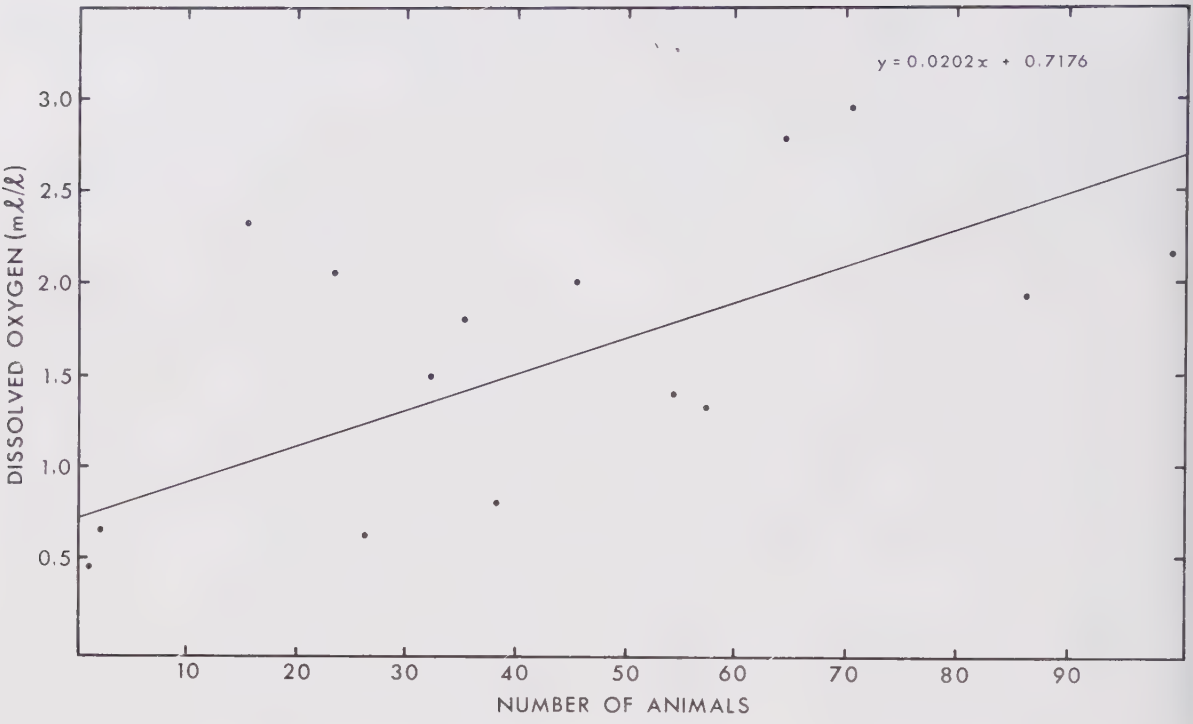

Fig. 5: Relationship between red-crab abundance and dissolved oxygen level, September 1978

Table V: Dissolved oxygen concentrations, salinity and temperature on the sea bed in order of increasing depth and the number of red crab caught, September 1978

Depth (m)	Oxygen (mℓ/ℓ)	Temperature (°C)	Salinity (‰)	Number of crabs
295	0,28	11,24	34,99	0
313	0,39	10,75	34,91	0
339	0,45	10,40	34,93	1
347	0,65	10,28	34,51	2
354	0,33	10,19	34,92	0
384	0,63	10,47	34,55	26
428	0,81	8,65	34,35	38
524	1,41	7,45	34,59	54
540	1,34	7,45	34,65	57
646	1,50	6,68	34,61	32
649	2,02	5,78	34,49	45
664	1,81	6,29	35,56	35
664	2,20	5,59	34,49	99
666	2,06	6,09	34,55	23
701	1,96	5,76	34,48	86
756	2,33	5,38	34,49	15
797	2,98	4,58	34,46	70
834	2,81	4,56	34,46	64

parameters that govern distribution of the red-crab population and the sexes individually. The possibility is not, however, excluded that migration, recruitment patterns or bottom topography may influence distribution.

Females are dominant in shallower water (295-395 m) and it is possible that they can tolerate lower dissolved oxygen levels and higher temperatures than males, which are dominant in deeper waters (638-849 m) where lower temperatures and higher dissolved oxygen concentrations prevail.

Generally, however, the correlation between the dissolved oxygen values of the bottom water and the number of *Geryon quinquedens* caught is good (Table V). Figure 5 represents the linear regression which was calculated as:

$$y = 0{,}02016\,x + 0{,}71760$$

where y = dissolved oxygen values (mℓ O_2/ℓ)
and x = number of animals caught.

From Figure 5, it is evident that dissolved oxygen values are directly proportional to the number of animals caught, the results being statistically significant at the 0,5-per-cent level.

Low bottom oxygen levels off the South West African coast have been documented by Hart and Currie (1960, p.192) who stated that " . . . off South West Africa there is a very rapid decrease (of oxygen content) with depth in the inshore waters, so that even in normal conditions in this region a content of less than 1 mℓ O_2/ℓ is found in the vicinity of the sea-bed on the continental shelf." Furthermore, from vertical sections of dissolved oxygen, Hart and Currie *(op.cit.)* deduced that, beyond the continental shelf, bottom dissolved oxygen increases with depth — a finding borne out by the values of dissolved oxygen listed in Table V. Stander (1964) described the presence of a well defined layer of minimum oxygen which is most conspicuous between latitudes 10°S and 18°S along the coast of South West Africa. He concluded that, at a depth of 300-350 m, this layer has an oxygen content of less than 0,55 mℓ/ℓ and that the condition is aggravated by the oxygen consumption of decaying organic matter following the annual spring phytoplankton bloom.

The species survives at extremely low levels of dissolved oxygen and tolerates a temperature range of more than 7°C, though this range could be much wider because the maximum depth at which it lives was not determined during the two surveys.

Much work must still be done before a complete understanding of the species in local waters is attained. Aspects that will receive attention in future surveys are north-south distribution, maximum depth of occurrence, moulting patterns, growth and embryology.

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1980

A NOTE ON SWARMS OF *NYCTIPHANES CAPENSIS* (HANSEN) LARVAE OFF SOUTH WEST AFRICA

R. M. THOMAS

Orange-red patches on the sea surface inshore at Henties Bay, South West Africa, were found to be high concentrations (81 x 10^3 individuals/litre) of euphausiid larvae. The possible causes of the phenomenon are discussed.

Daar is vasgestel dat die oranjerooi gekleurde kolle oppervlakwater wat aanlandig by Hentiesbaai in Suidwes-Afrika aanwesig was, deur hoë konsentrasies (81 x 10^3 individue/liter) van larvale eufausiïede veroorsaak is. Die moontlike oorsake van hierdie verskynsel word bespreek.

On 17 November 1977, R.V. *Kuiseb* was returning to Walvis Bay after a fishing survey. At 18h00, while off Henties Bay (Fig. 1), bright orange-red plumes were seen on the water surface. These were about 10 m long and 0,3 m wide and appeared to be confined to the top 0,5 m of water. They were orientated in a SW-NE direction and were observed sporadically between Henties Bay and Wlotska's Baken.

The sea was calm and the water was very clear. The sea surface temperature was taken by thermometer and was between 16,0 and 16,6°C.

A bucket was thrown into the centre of one of the plumes and a sample of 375 mℓ was taken by dipping a sample jar into the bucket. The sample was preserved with formalin. On return to the laboratory, the sample was concentrated to 200 mℓ by pouring off the supernatant liquid, and the settled volume of the original sample was found to be 30 mℓ/375 mℓ (or 80 mℓ/ℓ). Different larval stages of the euphausiid *Nyctiphanes capensis* (Hansen) were identified using Boden (1955). Two aliquots, of 11 mℓ and 19,5 mℓ, were taken and the number of each larval stage present was counted (Table I). No other zooplankton species were present. Total counts showed an original concentration of about 81 000 individuals per litre which, by any standards, is a very high concentration of zooplankton. Stomach contents were

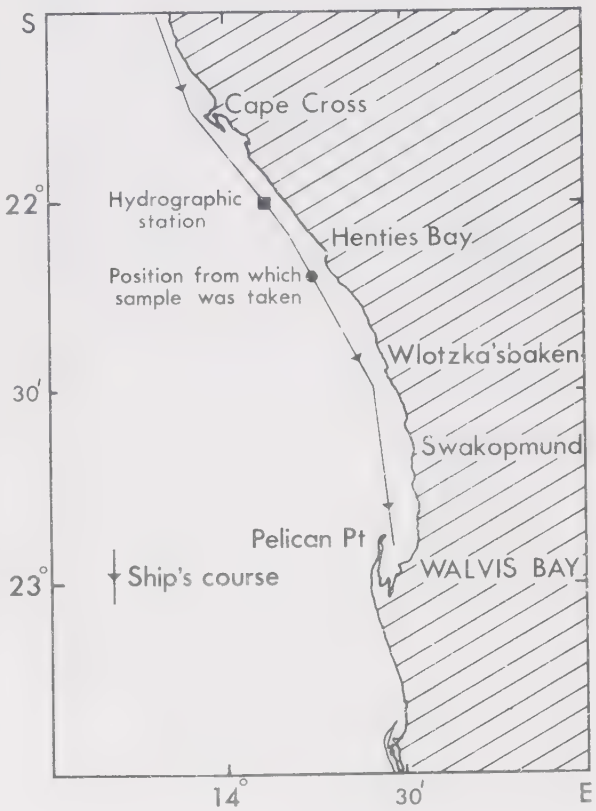

Fig. 1: Position of *Nyctiphanes capensis* swarm and of routine environmental station sampled separately

Table I: Counts and numbers per litre of each different larval stage for both aliquots

Larval stage	Aliquot 1 (11 mℓ)		Aliquot 2 (19,5 mℓ)	
	Count	Number/ℓ	Count	Number/ℓ
1st calyptopis	385	18 700	636	17 400
2nd calyptopis	378	18 300	610	16 700
3rd calyptopis	670	32 500	1 265	34 600
1st furcilia	194	9 400	278	7 600
2nd furcilia	70	3 400	128	3 500
3rd furcilia	7	300	8	200
Total	1 704	82 600	2 925	80 000

Table II: Hydrographic stations at 22°00'S, 14°07'E

Date	Sounding (m)	Depth (m)	Temperature (°C)	Oxygen (mℓ/ℓ)	Salinity (‰)	Thermocline depth (m)
12/11/77	18	0 15	14,77 11,57	6,40 0,01	34,94 —	15
29/11/77	20	0 15	15,50 11,79	6,10 0,20	35,00 —	3,5

examined and were found to contain green flagellates (Euglenophyceae and Chlorophyceae) which are commonly found in warm water (I. Kruger, Sea Fisheries Institute, personal communication).

Wind records taken from Pelican Point show that, for 3 weeks previously, the wind regime was dominated by northerly and westerly winds (i.e. downwelling winds). Synoptic oceanographic data (sea surface temperature, 10-day means) showed a warm intrusion into the area. Apart from surface temperature, no physical parameters were measured when the sample was taken, but temperature, salinity and oxygen were measured by R.S. *Sardinops* at a station 20 miles to the northwest on 12 and 29 November (Table II). Considering the consistency of the wind regime, it is not unreasonable to apply the data from the hydrographic station to the sample site. Notable features are the pronounced thermocline (identified on bathythermograph traces), the warm surface layer and the very low dissolved oxygen values at a depth of 15 m.

It is possible that the low-oxygen water may have been shallower at the sample site forcing the *N. capensis* larvae to the surface. Internal waves travelling along the thermocline could then cause larvae to aggregate into plumes (their orientation was correct for wave fronts generated by northwest winds). No aggregations of larvae were observed at the hydrographic station on either occasion (on both dates the station was worked at 06h00, the breeze being moderate and wave height 1 m). A catch of pilchard was made in the area shortly after the sample was taken, the shoal being close to the surface. Stomach contents showed that they had been feeding on euphausiid larvae.

As far as can be ascertained, this is the first time that any plumes of zooplankton have been both observed and sampled off Southern Africa. It is also the first documentation of swarming euphausiid larvae. Swarming is a common characteristic of adult euphausiids in many parts of the world. It is well known in Antarctic waters (Marr 1962, Kalinowski 1978, Jażdżewski *et al.* 1978, Sahrhage *et al.* 1978), but has also been recorded in other areas: in the Bay of Fundy (Bigelow 1924), in the Peru Coastal Current (Gunther 1936), off New Zealand (Fenwick 1978), in the Mediterranean Sea (Fisher *et al.* 1953) and in the Barents Sea (Zelickman 1960). L. Hutchings (Sea Fisheries Institute, personal communication) has seen euphausiid swarms off the Cape. Cram and Schülein (1974) observed extensive areas of surface euphausiids off South West Africa, though these were not as densely packed as those, for example, in the Antarctic. Off South West Africa, euphausiids are often encountered as a scattering layer (d'Arcangues 1977).

Marr (1962) records various observations which prove that Antarctic krill can form distinct shoals, like fish shoals, with each individual being orientated in the same direction, neighbours being separated by equal distances and the shoal moving as a single cohesive unit, changing its shape but not its unity. Swarms are not limited to spawners (Marr *op.cit.*). Adult euphausiids are strong swimmers and presumably find the same advantages in shoaling behaviour as do pelagic fish, though Marr *(op.cit.)* also believes that the larvae assemble into swarms immediately after hatching. The means whereby such small organisms (< 1 mm long) manage to aggregate themselves into such large numbers is unknown, but that they can is not inconceivable. Gunther (1936) has described similar streaks of surface discolouration caused by euphausiid larvae off Peru.

From the above discussion, it is thought possible that these larvae actively swarmed, with the physical environment merely providing the appropriate stimulus. Other reasons for considering it unlikely that the larvae were concentrated passively or actively in response to oxygen deficiency are listed below:

(i) Adult *N. capensis* are known to be tolerant of low oxygen concentration. d'Arcangues (1977) found concentrations of 274 individuals/m^3 at 1,3 mℓ 0_2/ℓ in her Miller-net studies. Larvae may, however, be less tolerant.

(ii) The occurrence of such small compact swarms suggests a higher degree of aggregation than is possible by mechanical concentration alone or by conformity to oceanographic features.

(iii) The concentration of larvae at 81 000 individuals/ℓ would be a very poor way of escaping from low oxygen, because the oxygen demand for such a dense swarm would be enormous.

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COMPARATIVE EFFICIENCY OF BEAM AND OTTER TRAWLS AT CATCHING DEMERSAL FISH OFF SOUTH WEST AFRICA

L. BOTHA and A. I. L. PAYNE

A direct comparison is made of the catch rates of a beam trawler and an otter trawler fishing simultaneously in the same area. The beam-trawl catches were smaller in volume but consisted of a greater proportion of soles and, per equivalent unit of fishing time, the beam trawler was eight times as effective at catching soles as the otter trawler. During the experiment, the beam trawler took fewer small soles and far less hake, an off-bottom species, than did the otter trawler. Physical damage to the sea-bed or to benthic organisms by beam trawls is indicated to be fairly low. It is concluded that introduction of beam trawlers into the South West African sole fishery should be carefully controlled because of the unknown value of the optimum sustainable yield of the species, coupled with the high sole-catching efficiency of the beam-trawl technique.

Die vangkoerse van 'n balktreiler en 'n ottertreiler wat gelyktydig in dieselfde gebied visvang, word regstreeks vergelyk. Die volume van die balktreilvangste was kleiner, maar hul het 'n groter proporsie tongvis bevat en, in gelyke visvangtyd, was die balktreiler agt maal doeltreffender vir die vangs van tongvis as die ottertreiler. Gedurende die eksperiment het die balktreiler minder klein tongvis gevang as die ottertreiler en veel minder stokvis, 'n spesie wat nie op die bodem self hou nie. Daar is maar geringe aanduidings van beskadiging van die seebodem of bentiese organismes deur balktreilers. Die gevolgtrekking is dat behoedsame beheer uitgeoefen moet word oor die inbring van balktreilers in die Suidwes-Afrikaanse tongvisvissery, om twee redes: omdat die optimum volhoubare opbrengs van die spesie voorasnog onbekend is, en omdat die balktreiltegniek so uitmuntend doeltreffend is vir die tongvisvangs.

A trawl fishery based on hake *(Merluccius capensis)*, sole *(Austroglossus microlepis)*, kingklip *(Genypterus capensis)* and kob *(Johnius hololepidotus)* commenced operations from Walvis Bay in 1958, using predominantly the Icelandic two-seam otter trawl (Lucks *et al.* 1973). Early in 1973 a first attempt was made to use a beam trawl on inshore sole (Lucks *et al., op. cit.*), but was soon abandoned. In 1976, a fresh request for permission to operate a beam trawl was made to the local management authority. Because of the long-standing controversy surrounding that method of fishing in the Northern Hemisphere and concern about the deleterious effects which it might have on local demersal fish stocks, it was decided to first conduct preliminary comparative fishing tests to serve as a basis for management advice. Three main objectives were identified, (a) to compare the catching efficiency of a beam trawl with that of a conventional otter trawl, (b) to compare the effects of the two gears on local demersal fish stocks, and (c) to assess as far as possible, within the limits of the experiment, the effects of beam trawling on benthic organisms. The tests were conducted off Walvis Bay in May 1977 and the present paper reports briefly on the outcome.

MATERIAL AND METHODS

Experimental trawls were conducted from two commercial vessels fishing in close proximity to each other on 26—27 May 1977. Trawling was done north-west of Walvis Bay at 22°20′S, 13°50′E and an average depth of 100 m.

The vessel used for otter trawling was M. F. V. *Benguella Astra*, a 31-m steel-hulled freezer stern-trawler of 201 GRT capable of developing 447 kW. The net was a small, standard commercial sole trawl equipped with steel otter boards and with a minimum mesh size of 75 mm.

Beam trawls were operated from the M. F. V. *Aaltje*, a Dutch-built cutter, fully equipped for beam trawling, 28 m in length, 125 GRT and capable of developing 567 kW. Navigational aids on this vessel, in addition to the radar, echo-sounder and Decca Navigator also fitted on the *Benguella Astra*, included a Decca Plotter which enabled the vessel to trawl in specified areas with greater precision. The vessel was built as a beam trawler in accordance with the high standard of vessel stability and safety required of such vessels by Dutch authorities.

The beam-trawling gear consisted of two identical 75-mm mesh-size nets, one dragged on each side of the vessel from a heavy horizontal boom fixed to the main mast. The beam of each net was a 10-m hollow steel tube fitted on short struts to 80-cm skates. The chain headline on each net was fixed tautly to the vertical struts in such a manner that it provided an effective fixed vertical net opening of only about 20 cm above ground level. The belly of the net was cut far back and partially replaced by four, short, 6-mm diameter short-link chains spaced at regular intervals directly in front of the footrope. The footrope was heavily wrapped with polyethylene rope along its central section to give it a diameter of about 40 cm. A hefty 12-mm diameter long-link chain was suspended between the skates, followed at spaced intervals by four 6-mm diameter short-link chains also attached to the skates. These five chains constituted the main tickler chains of the net and were arranged in loose loops extending backwards towards the footrope and running roughly parallel to its curvature.

Average towing speed was 4 knots on the *Benguella Astra* and 6 knots on the *Aaltje*. *Benguella Astra* consequently covered a ground trawling distance of about 10 nautical miles in a standard drag of 2½ hours, while *Aaltje* covered 15 miles in the same time. No standardization of the data from each vessel was made because it was not considered necessary for the purpose of the survey. Standard commercial practices and fishing techniques were adhered to at all times.

On each vessel the catch per species per drag was recorded, and samples of sole were measured for total fish length. The latter was recorded to the nearest centimetre below, while the catch per basket of fish was converted to mass by means of the known mass of a basket full of fish.

RESULTS

Ten hauls were made by the *Aaltje* and five by the *Benguella Astra*. Although derived from only a few hauls, the data recorded on the *Benguella Astra* were considered as representative of catches made with conventional trawling gear in the area.

Comparison of catching efficiency

A summary of total catches made by each vessel during the experimental period appears in Table I, where the total fishing effort and catch rate are also given.

Table I: Summary of catches made on the M. F. V. *Aaltje* and the M. F. V. *Benguella Astra*, 26-2 May 1977

	Aaltje	*Benguella Astra*
Mass of total catch of all species (kg)	4 556	2 717
Fishing effort (h)	25,25	12,75
Catch per unit effort (kg per hour fished)	180,4	213,1

It is clear from Table I that, despite its greater power, the *Aaltje* was some 15 per cent less efficient than the *Benguella Astra* as to pure bulk of catch per equivalent unit of fishing time. If it is considered that the *Aaltje* catches reflected in Table I represent the combined catches of two beam trawls, the catch rate of each beam trawl was only 90,2 kg per hour trawled, which was 58 per cent less than the catch-rate performance of the single conventional trawl used on the *Benguella Astra*. The superior catch rate attained by the *Benguella Astra* no doubt resulted from its high-lifting headline (± 2 m) and wide sweep (estimated as 100 m between the otter boards), compared to the very low (20 cm) headline lift and fixed 10-m horizontal sweep of each beam trawl. As will be seen in the next section, the differences in net construction resulted in widely divergent species catch compositions made with each type of net. Whereas, therefore, the beam trawl compared unfavourably with a conventional trawl in terms of bulk catch per unit of fishing effort, its efficiency cannot be properly judged without a comparison of catch rate by individual species.

Comparative effects of trawls on fish stocks

The recorded catch per species per drag per vessel and other relevant information are shown in Table II.

It is evident from Table II that, whereas 38 per cent of the *Aaltje's* total catch consisted of sole, that species constituted only 4 per cent of the catch made by the *Benguella Astra*. In respect of catch rate of sole, the *Aaltje's* 69 kg per hour trawled was more than eight times higher than the 8 kg per hour of the *Benguella Astra*. Each single beam trawl, therefore, was four times more efficient for catching sole than the conventional trawl net.

Monk *Lophius piscatorius* constituted 18 per

Table II: Details of catches made on the M.F.V. *Aaltje* and M.F.V. *Benguella Astra*, 26 — 27 May 1977

Date	Time	Catch (kg)				Duration of drag (h)
		Sole	Hake	Monk	Others	
		M. F. V. *Aaltje*				
26/5	1330—1600	149	158	70	35	2½
26/5	1630—1900	175	88	62	35	2½
26/5	1930—2200	149	201	105	35	2½
26/5	2230—0100	123	105	105	35	2½
27/5	0130—0400	140	280	123	35	2½
27/5	0430—0730	193	185	88	35	3
27/5	0830—1045	210	140	70	35	2¼
27/5	1130—1400	149	193	70	35	2½
27/5	1430—1700	210	175	70	35	2½
27/5	1730—2000	245	140	35	35	2½
Totals		1 743	1 665	798	350	25¼
Portion of catch (%)		38	37	18	8	
Catch per unit effort		69	66	32	14	
		M. F. V. *Benguella Astra*				
26/5	1230—1330	15	450	0	45	1
26/5	1415—1745		No catch			3½*
26/5	1815—2130	23	1 170	0	45	3¼
26/5	2230—0300	15	45	0	45	4½
27/5	0500—0900	45	720	9	90	4
Totals		98	2 385	9	225	16¼
Portion of catch (%)		4	88	0,3	8	
Catch per unit effort		8	187	1	18	

* This trawl was ignored for calculation purposes

cent of the total catch of the *Aaltje* but less than 1 per cent of that of the *Benguella Astra*. Catches of hake were also different. Whereas 88 per cent (187 kg/h) of the *Benguella Astra's* catch consisted of hake, the comparable figure for the *Aaltje* was only 37 per cent (66 kg/h), i.e. some three times less for the two beam trawls combined.

From the foregoing, it is clear that the beam trawl is highly efficient at catching bottom fish species such as sole and monk, but much less efficient for the catching of off-bottom species such as hake. No doubt the observed differences can be related to basic differences between the beam trawl and the conventional trawl employed during the experiments. The low headline height of the beam trawl would have effectively limited its catching of hake only to those short periods when the net was actually shot or hauled. A few hake may, however, also have been taken either hard on the bottom or, at times, when the net presumably lifted off the bottom during the tow. The higher speed of towing by the beam trawler made the latter occurrence a distinct probability.

The vastly superior catching performance of the beam trawl compared to the conventional trawl for both sole and monk can without doubt be ascribed to the tickler chains carried on the beam trawl. The present experiments have merely confirmed well known overseas experience on the chains' effectiveness.

In respect of species other than sole, hake and monk, it was noted that both types of nets performed equally well (see Table I — others). The category "others", mainly swimming-crabs and jelly fish but also a few sponges, molluscs and occasionally a gurnard *Trigla* spp. and a kingklip amounted to 8 per cent in both types of net. However, the crab content in the beam-trawl catches was always higher.

Effects of the beam trawl on benthic organisms

As mentioned in the previous section, considerably greater quantities of crabs were caught in the beam trawls, but they nevertheless averaged only ± 18 kg per drag (two nets). Numbers of small (± 8 cm long) gobies *Sufflogobius bibar-*

batus were noticed floating in the water after the beam trawl had been hauled up; they were not seen from the *Benguella Astra*. Numbers of polychaete worms of various species were similarly noticed in and around the beam-trawl net but, because of the relatively large mesh size of the nets, no quantitative assessment of the numbers of these organisms was attempted.

Polychaetes were absent from catches made with the conventional trawl. It seems clear, therefore, that in contrast to the conventional trawl, the beam trawl dislodged numbers of mud-dwellers such as polychaetes from the substrate. All the polychaetes seen on the deck were in a whole condition and apparently not damaged in a physical sense. The crabs brought on board by both types of nets were very much alive and not damaged in any way. A few delicate "nautilus" shells, completely undamaged, were also found in the beam-trawl nets. All fish, including soles, caught by both types of nets were undamaged and in a good condition.

From the foregoing observations it would appear that the beam trawl dislodged many more benthic organisms than the conventional trawl. However, the actual physical damage to those organisms appeared to be minimal. Short of mounting extensive and expensive experiments (using underwater cameras and/or divers and various small-meshed nets and grabs), little more than the foregoing could be concluded from the present experiment about damage to benthic organisms. Such experiments have, however, been conducted in the North Sea. De Groot (1973) reported extensively on the influence of trawls on the sea-bed. He found that damage to the sea-bed itself depended on the nature of the bottom and the speed of the bottom current. By making use of a transit- sonar, he found that the greatest damage was done to a soft sandy bottom, where the trawl track was still visible after 150 minutes. On a muddy bottom the trawl track disappeared rapidly and was still only just visible after 30 minutes. De Groot (*op. cit.*) furthermore found that hydroids were damaged extensively by the chains. Other invertebrate benthic organisms were damaged to varying (largely undetermined) degrees, both by the net itself and the chains. He concluded, however, that there was no indication of serious damage to the sea-bed nor any decline in available food for fish following large-scale introduction of beam trawls into the North Sea sole fishery.

During the present experiments the beam trawls were clearly dragged hard on the bottom, as was evidenced by the "polished" surfaces on the gear. The skates were polished on their flat undersides only. There was no indication of polishing on any other part of the beam trawl, except of course on the tickler chains. This would seem to indicate that the beam trawl does not actually sink into the mud, but glides on it. It is evident, therefore, that the beam trawl is not ploughed through the mud as is often alleged. Short of actually observing the chains in action on the sea-bed, it is our considered opinion that the high towing speeds would cause them to merely rake the sea-bed rather than to dig in deeply. Certainly the action of the chains on many of the animals caught was not destructive, as was evidenced by the excellent quality of the fish caught and the undamaged crabs and even delicate "nautilus" shells brought on deck. It would seem inaccurate to consider the tickler chains as having a pulverizing effect on anything with which they came into contact while trawling. Whereas quantities of benthic organisms such as polychaete worms may therefore actually be dislodged from the mud, as was indeed the case, the actual mortality inflicted on them may not be particularly high.

Length frequency distribution of soles

A total of 1 047 soles was measured for total length on board the *Aaltje* and 367 (all soles caught) on the *Benguella Astra*. The length frequency distributions of the two samples are compared in Figure 1. Although the relatively small sample of the *Benguella Astra* should be treated with some circumspection, it is seen that both vessels fished essentially on the same group of soles. Both vessels employed a nominal mesh size of 75 mm, yet the beam trawl caught considerably fewer small soles than the conventional trawl. More important, however, is the fact that the beam-trawl net in no way impaired the escapement of small soles; in fact, the results would seem to indicate that escapement was enhanced. This would not be unexpected, because it is known that the selectivity of a trawl net is inversely related to total catch size. It can be concluded, therefore, that the beam trawl with its (intended) smaller by-catch of species such as hake, has a conservational advantage over the conventional trawl net in this respect.

Food organisms of sole

No feeding study had been planned for the experiment because it is well known that soles feed on benthic organisms such as polychaete worms. However, a casual inspection of a number

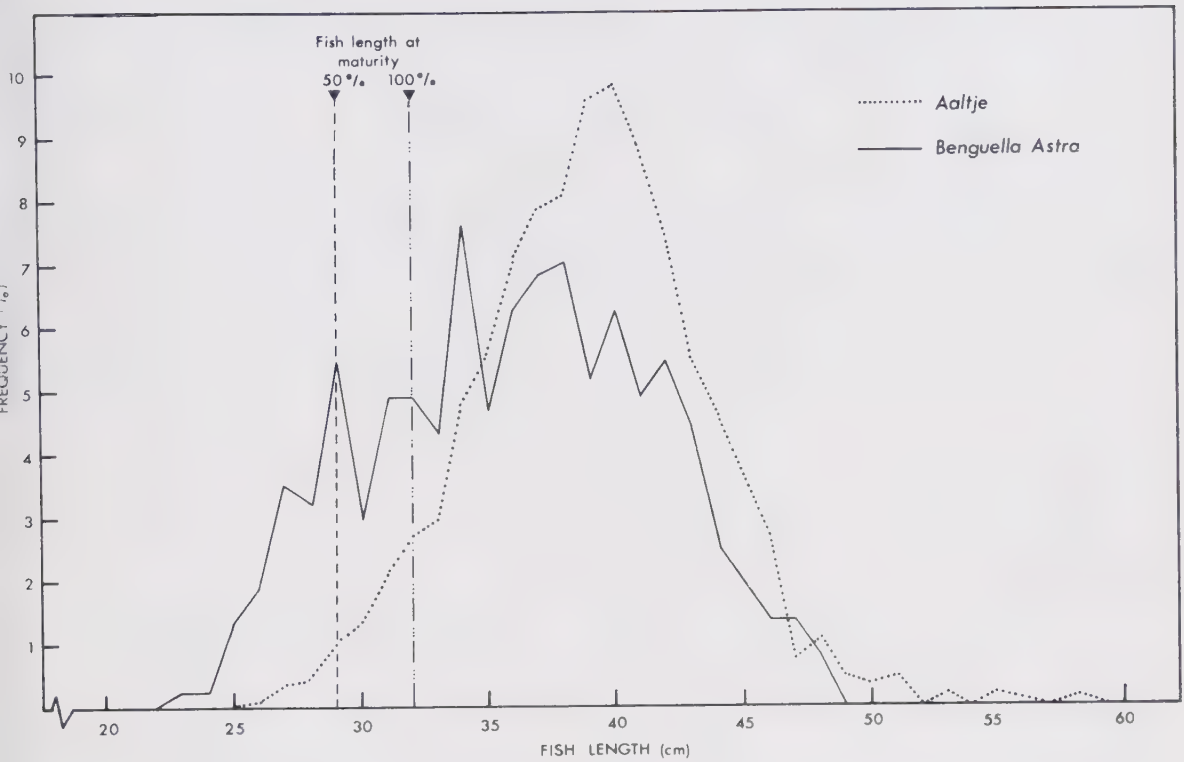

Fig. 1: Comparative length-frequency distribution of soles caught by the beam and the otter trawler

of sole stomachs revealed surprisingly large numbers of gobies in various stages of digestion. It would appear, therefore, that the South West African sole is not as heavily dependent on benthic organisms for food as was hitherto presumed to be the case. They do, in fact, also feed extensively on small off-bottom nectonic fish which abound in the area.

Dutch experiments (De Groot 1973) have shown that beam trawls dislodge polychaetes from the mud and thereby increase the availability of food to soles. Sustained use of beam trawls on a large scale has apparently resulted in an increase in the growth rate of North Sea soles.

DISCUSSION

The beam trawling method employed on the M. F. V. *Aaltje* is clearly a highly efficient selective method of catching bottom species such as soles and monk, at the same time reducing to a considerable extent the catch of "unwanted" species such as hake. Short of actually observing the tickler chains in action on the sea-bed, their effect on it and on benthic organisms remains somewhat debatable. However, there is a considerable body of evidence which seems to indicate that tickler chains are not as destructive as is often supposed. Significant in this respect is the fact that up to 700 beam trawlers with very heavy tickler chains have caught soles in the North Sea for many years. Soles are nevertheless still caught there in reduced quantities and there is no evidence of catastrophic damage to the sea bed.

The four short chains attached just in front of the footrope of the net of the the *Aaltje* may, as has been pointed out before, be considered as largely replacing the belly of a conventional trawl net. For this reason their effect on the sea-bed may be ignored. The main effect on the sea-bed and benthic organisms would be that of the four long tickler chains suspended from the skates. It is, in the light of the foregoing, considered that the four

tickler chains as used on the *Aaltje* would not cause undue damage to the sea-bed or benthic organisms. Any reduction in the number of chains would cause a significant reduction in the catch of soles, and four tickler chains could therefore be regarded as necessary and acceptable for beam-trawl operations in southern Africa.

As has been mentioned before, the beam-trawl nets on the *Aaltje* caught an average of 37 per cent of hake, despite the use of a low headline. This figure exceeds the legal maximum of 30 per cent of hake allowable when using a 75-mm mesh net in southern Africa. Lucks (1972) conducted a mesh selectivity study on the West Coast sole, and the conclusion reached, based on age-at-maturity, was that a mesh size of 75 mm should be applied to the fishery. Clearly, a 110-mm mesh size (that in use for hake fishing) would reduce the catch to virtually zero. Beam trawlers should therefore be permitted to use a 75-mm mesh size in their sole-directed operations despite the strictly speaking inadmissible by-catch of hake.

The use of the beam trawl has introduced an interesting and possibly useful method of assessing the absolute abundance of catchable soles in a given area at a given time. The horizontal opening of the beam trawl is fixed and known and, because the tickler chains ensure that most soles are taken by the net, it is relatively simple to calculate the number of soles caught in the area trawled. Such a calculation was done for the present experiments, and gave an absolute abundance of 845 soles of catchable size (with a 75 mm mesh size) per square kilometre in the area concerned (i.e. 0,001 soles per m^2). The figure is rather low but does not include juvenile soles or take account of the catching efficiency of the net. Furthermore, it is known that beam-trawl catches have, in certain areas, been three times as high, which would give an absolute abundance in such areas of about 2 535 soles per km^2. Whereas these values are somewhat speculative at this stage, large-scale analyses of beam-trawler catch statistics over a wide area and over a longer period of time may prove to be useful in estimating sole abundance.

The results indicate that the introduction o beam trawlers similar to the *Aaltje* into the Soutl West African trawl fishery could increase the fishin mortality on soles per vessel by a factor of abou eight compared with conventional trawlers, bu would reduce the fishing mortality on hake by a factor of three. It is, therefore, evident that th introduction of beam trawlers should be permitte only in a careful and controlled manner, up to a maximum which would not overshoot the optimun sustainable yield of the sole stock. Because thi optimum sustainable yield is at present unknown continual and regular monitoring of the stock must be carried out, particularly as sole forms a most valuable component of the small trawl fishery of South West Africa (Lucks *et al.* 1973).

ACKNOWLEDGEMENTS

The full and cordial cooperation of the owners and captains of the experimental vessels is gratefully acknowledged. Mr A. P. van Dalsen is thanked for his help during the experiment. The technical advice of Mr D. Moore, formerly of this Institute, was especially helpful and went a long way towards establishing the necessary contact with practical fishermen.

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A CHECKLIST OF SOUTH WEST AFRICAN MARINE PHYTOPLANKTON, WITH SOME PHYTOGEOGRAPHICAL RELATIONS

I. KRUGER

The components of the marine microflora off South West Africa between 17°S and 28°30'S and off shore to 10°E are listed systematically. Revision of taxonomic units was only done in so far as available literature permitted. A listing on this scale of South West African species, in which only the very small flagellated types remain unidentified, has not before been published. The 537 species found are compared with those of two other regions, the Mediterranean Sea and the South-West Indian Ocean, these being geographically the nearest that have been well enough documented. The world distribution of the identified diatoms and dinoflagellates is also discussed. Floristically, South West African waters are undistinguished, sharing 73 per cent of the species with the Mediterranean Sea and 72 per cent with the South-West Indian Ocean. Only a few diatoms, notably *Delphineis karstenii* (Boden) Fryxell which is important in the diet of commercially valuable pelagic fish, are restricted to South West Africa and adjacent South African waters.

Die komponente van die mariene mikroflora van Suidwes-Afrika, tussen 17°S en 28°30'S en aflandig tot 10°E, word sistematies gerangskik. Hersiening van die taksonomiese eenhede was alleen moontlik in dié gevalle waar die beskikbare literatuur daarop betrekking gehad het. 'n Lys op so 'n groot skaal van Suidwes-Afrikaanse soorte, met net die kleinste flagellate nie geïdentifiseer nie, is nog nooit voorheen uitgegee nie. Die 537 spesies van Suidwes-Afrika word vergelyk met dié van die Middellandse See en die Suidwes-Indiese Oseaan, wat geografies die naaste gebiede is wat voldoende beskryf is. Die wêreldwye verspreiding van die geïdentifiseerde diatome en dinoflagellate word ook bespreek. Floristies is die Suidwes- Afrikaanse waters nie juis merkwaardig nie, aangesien 73 persent van die spesies daarin, ook in die Middellandse See en 72 persent in die Suidwes-Indiese Oseaan voorkom. Net 'n klein aantal diatome, veral *Delphineis karstenii* (Boden) Fryxell wat 'n vername bestanddeel is van die dieet van kommersieel waardevolle pelagiese vis, is tot Suidwes-Afrika en aangrensende Suid-Afrikaanse waters beperk.

Hart and Currie (1960) reported that previous iological studies such as that of Karsten (1906), ho identified material derived from plankton auls north (e.g. 16°36'S; 11°45,5'E), west (e.g. 5°27'S; 6°8,2'E) and south (e.g. 33°20,3'S; 3°58,2'E) of the survey area covered in this eport, and Hendey (1937), with stations also in ie south (e.g. 33°6,5'S; 17°45,2'E) gave a sound undation on which to base many of the present ientifications. Hentschel (1933 and 1936), with ations within the South West African investiga- onal area (Fig. 1), helped to unravel the basic icrobiology of the study area.

Plankton sampling in South West African waters as been frequent in recent years and has made he taxonomic listing possible. The list is based on hytoplankton studies of the Sea Fisheries Institute nd those of other workers who collected samples eaward to 10°E and between 17°S and the Orange River (28°30'S).

Phytoplankton samples, comprising 574 from N50V nets and 671 from diatom bottles, were nalysed in detail, i.e. identifying all the species of he taxonomic groups present (see checklist). Only he very small flagellates were not accurately dentified and they were listed as "flagellates". All dentified species are listed, together with those not found in the author's samples but noted by other workers. With the aid of available literature, species names have been updated where possible.

The South West African species were checked for presence or absence against checklists of the phytoplankton of the Mediterranean Sea and the South-West Indian Ocean in order to determine the phytogeographic relationship between South West Africa and the other two areas. These two areas were chosen because, according to available literature, the phytoplankton has been well sampled and analysed, and they therefore appear to be the closest well surveyed oceanic regions. The phytoplankton of geographically closer areas, for instance Angola and North-West Africa, seems to be not as well studied. No detailed species list of the west coast of southern Africa has yet been published.

In the following section, full details of species identification methods, study area, literature used for comparative distribution studies, and abbreviations and codes used in Tables, are given. In the results section is an account of all the taxa identified in South West Africa and their presence or absence in the other two areas. The world distribution of the diatoms and the identified dinoflagellates is also discussed.

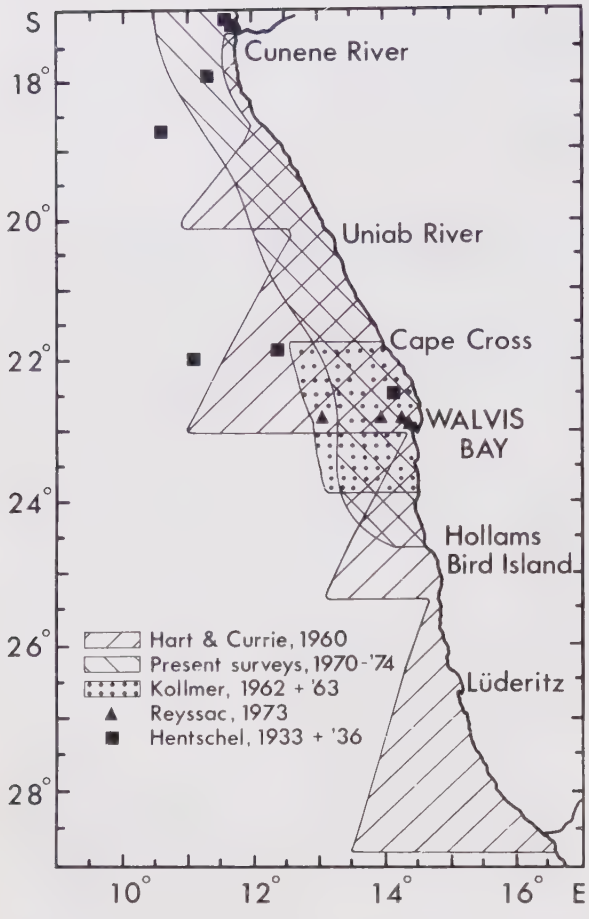

Fig. 1: Areas and stations studied by different workers off South West Africa

between March and October 1950, was extensive, reaching on occasion as far as 312 km off shore. The hydrology and the phytoplankton off South West Africa were discussed by them in detail.

Kollmer (1962, 1963) investigated the area from Cape Cross to Conception Bay to about 156 km off shore during the years 1958—1960. His work was mainly concerned with the annual cycle of phytoplankton. Pieterse and Van der Post (1967) studied red-water phenomena in Walvis Bay from 1964 to 1966 (stations not shown in Figure 1) and gave a good account of similar work by others. They listed all the species of phytoplankton they found in the Bay.

Reyssac (1973) studied the diatoms and dinoflagellates of four stations worked off Walvis Bay from June 1965 to April 1966 to nearly the same distance off shore as Kollmer (1962).

During the period 1959—1961, the Sea Fisheries Institute conducted quarterly cruises in the same area as that forming the basis of the present report. The results have not been published, but the species lists were compared with the more recent ones to determine whether any other species were collected during those years. However, none were found (Sea Fisheries Institute, unpublished data 1959—1961).

During the studies of fish population dynamics of 1970—1974 (Cape Cross Programme), sampling took place between 17°S and Hollams Bird Island (24° 40'S) and seaward to 111 km. Results of the surveys in respect of phytoplankton, hydrology and pelagic fish appear in several unpublished internal reports, viz. Anon. (1971), Kruger (1972), Visser *et al.* (1973) and Wessels *et al.* (1974). Phytoplankton distribution and abundance in time and space was discussed in relation to hydrology and pelagic fish.

MEANS OF PRESENTATION

Details of areas studied

Figure 1 presents the boundaries of extensive surveys in the study area and some individual stations of other workers falling in the area.

Hentschel (1933 and 1936), whose stations appeared in Wüst *et al.* (1932), described the general biology of the South Atlantic Ocean and included a report on the phytoplankton species found in the samples taken by the "Meteor" Expedition during 1925—1927.

The survey of Hart and Currie (1960), conducted

Samples taken and species identification

For qualitative analysis, a Discovery-type net with 50-cm mouth diameter and fitted with 80-μm nylon netting, was hauled from 50—0 m (in areas deeper than 50 m) and from 5 m off the bottom in shallower areas. For quantitative analysis, a flight of three N.I.O. water-samplers was used to collect diatom bottle samples at standard depths to a maximum of 400 m.

Microscopic analysis of qualitative and quantitative samples was by means of a research microscope (light) with phase contrast. The counting methods of Nel (1968) were used for each type of sample. The literature used to identify the genera

Table I: Literature used in identification and updating

Taxonomic category	Literature
nophyceae	Sournia (1968b), Wille (1903)
sinophyceae	Fritsch (1935), Lemmermann (1903), Travers and Travers (1975)
ienophyceae	Fritsch (1935), Leedale (1967), Chapman and Chapman (1973)
nthophyceae	Fritsch (1935), Travers and Travers (1975)
illariophyceae	Allen and Cupp (1935), Boden (1950), Brunel (1962), Cupp (1943), Hasle (1965), Fryxell and Miller (1978), Hendey (1937 & 1964), Hustedt (1962), Karsten (1906 & 1907), Lebour (1930), Lemmermann (1903), Sournia (1970), Taylor (1967), Travers and Travers (1975)
coflagellineae	Deflandre (1952a), Gemeinhardt (1930), Travers and Travers (1975)
eocystaceae	Fritsch (1935), Lemmermann (1903)
ccolithaceae	Deflandre (1952b), Schiller (1930), Travers and Travers (1975)
smo- and Dinophyceae	Balech (1967), Braarud (1957), Pieterse and Van der Post (1967), Schiller (1933—1937), Sournia (1967, 1970 & 1972), Steemann-Nielsen (1934), Taylor (1976), Travers and Travers (1975)
raminiferida	Bé (1967), Boltovskoy and Wright (1976), Bremner (1978), Cushman (1918, 1924 & 1959), Newell and Newell (1977), Rhumbler (1901)
liolaria	Borgert (1901), Haeckel (1887), Haecker (1908), Newell and Newell (1977), Petrushevskaya (1972), Popofsky (1905), Schröder (1909, 1911 & 1929), Tregouboff and Rose (1957)
tinnida	Kofoid and Campbell (1929), Marshall (1969 a—k), Newell and Newell (1977), Travers and Travers (1975)
itrichida	Kudo (1960), Tregouboff and Rose (1957)
lotrichida	Kudo (1960), Hamburger and von Buddenbrock-Heidelberg (1911)

f species within the higher taxonomic categories sted in Table I.

onomic aspects

erature for identification — All South West ican phytoplankton species are listed in the cklist and are classified under their appropriate nomic categories as explained hereunder.

he algae are classified according to the system Chapman and Chapman (1973), the Foramini- da, Radiolaria and Tintinnida according to well and Newell (1977) and the Holotrichida Peritrichida after Kudo (1968). In the checklist, ae are for the most part classified under division d class but, in the case of the Classes Chryso- yceae and Haptophyceae (Division Chryso- yta), it was found necessary to subdivide into ler, sub-order and family. The protozoan groups raminifera, radiolarians and tintinnids) are ssified under phylum, class and order.

Constantly improving techniques in studying cro-organisms have led to a rather unstable tem in which affiliations are never firmly estab- ed and taxonomic transfers are frequent. Thus, for example, Fryxell and Miller (1978) have suggested that the abundant and economically important pioneer diatom *Fragilaria karstenii* Boden, which has long been known in South West Africa, be transferred to the Genus *Delphineis.*

The previously accepted nomenclature has been changed in this present list only where valid taxonomic revisions have been available to the author e.g. Sournia (*Trichodesmium,* 1968b; *Ceratium,* 1967), Hasle (*Nitzschia,* 1965), Balech (*Phalacroma/ Dinophysis,* 1967) Fryxell and Miller (*Fragilaria karstenii,* 1978) and Deflandre (silicoflagellates and coccolithophorids, 1952a,b).

Some further taxonomic updating for diatoms is to be found in Hendey (1937 and 1964), for diatoms and dinoflagellates in Sournia (1968a, 1970 and 1972) and in Taylor (1976) and for various groups in Taylor (1967), Travers and Travers (1975) and Tregouboff and Rose (1957). The most important works referred to for taxonomic changes of foraminifera are Boltovskoy and Wright (1976), Cushman (1959) and Bé (1967).

Literature for distribution comparisons — In order to check the presence or absence of South West African phytoplankton species in the Mediterran-

ean Sea and the South-West Indian Ocean, the most comprehensive available literature on these areas, containing checklists, was used. Main sources of reference for the Mediterranean Sea are Tregouboff and Rose (1957), Balech (1959), Léger (1971 a, b and 1972 a, b, c), Dowidar (1974) and Travers and Travers (1975), and for the South-West Indian Ocean, Nel (1968) and Taylor (1967).

In respect of the world distribution of the diatoms and dinoflagellates of South West Africa, the most useful publications on hand are Sournia (1970), Margalef (1973) and Reyssac (1973). Publications giving information on the world distribution of diatoms only are Lebour (1930), Hendey (1937 and 1964), Cupp (1943) and Hustedt (1962) and of dinoflagellates only, Lebour (1925), Schiller (1933—1937), Subrahmanyan (1968) and Taylor (1976).

Abbreviations and codes in Tables

Certain abbreviations and codes that are used in the checklist and Table IV are explained below.

Bent.	=	benthic diatoms indicated by "×"
Med.	=	Mediterranean Sea
S.W.I.O.	=	South-West Indian Ocean
c	=	cosmopolitan (all seas)
tt	=	tropical and temperate seas
t	=	tropical seas
ws	=	west coast of southern Africa
wes	=	west and east coasts of southern Africa
as	=	colder parts of the seas south of southern Africa
so	=	southern parts of all oceans
tl	=	tropical Atlantic
ttl	=	tropical and temperate Atlantic
z	=	world distribution not indicated
−	=	absence in the Med. or the S.W.I.O
+	=	presence in the Med. or the S.W.I.O.
?	=	approximate world distribution

RESULTS

Taxa identified in South West Africa

A total of 537 lower taxa were recognized, of which 508 were identified to species or infraspecific level and 29 to the genus level only. Unidentified species did not number more than one per genus. There were 200 genera and they are distributed among 15 higher taxonomic groups (see checklist and Table II). A total of 61 species not found in the samples is derived from the records of others (Table II).

Diatoms (61 genera) outnumbered all other groups. They were followed by dinoflagellates and tintinnids with 34 genera each and the radiolarians with 31. All the remaining taxonomic groups had fewer genera, i.e. foraminifera 19, coccolitho

Table II: Number of lower taxa identified per higher taxonomic group

Taxonomic group	Number identified to species level	Number identified to genus level	Number of genera/taxonomic group	Number of genera and species identified by others
Cyanophyceae	2	0	1	0
Prasinophyceae	3	0	2	1
Euglenophyceae	0	1	1	0
Xanthophyceae	1	0	1	0
Bacillariophyceae	180	4	61	24
Silicoflagellineae	9	1	3	0
Phaeocystaceae	0	1	1	1
Coccolithaceae	15	0	10	8
Desmophyceae	4	0	2	0
Dinophyceae	149	5	32	12
Foraminiferida	18	7	19	11
Radiolaria	34	6	31	0
Tintinnida	91	4	34	4
Peritrichida	1	0	1	0
Holotrichida	1	0	1	0
Total	508	29	200	61

ble III: Frequency-of-occurrence of South West African higher taxonomic groups and main genera in the Mediterranean Sea and the South-West Indian Ocean*

axonomic groups and genera	South West Africa		Mediterranean Sea		South-West Indian Ocean	
	Number of species of higher groups	Number of species of main genera	Number of species of higher groups co-occurring	Number of species of main genera co-occurring	Number of species of higher groups co-occurring	Number of species of main genera co-occurring
iatoms	184		142 (77%)		152 (83%)	
Bacteriastrum		8		6		7
Biddulphia		8		7		6
Chaetoceros		46		37		40
Coscinodiscus		14		13		12
Nitzschia		6		6		6
Rhizosolenia		20		18		20
Thalassiosira		8		7		6
Thalassiothrix		6		3		6
ilicoflagellates	10		7 (70%)		5 (50%)	
Dictyocha		8		6		4
occolithophorids	15		10 (67%)		6 (40%)	
inoflagellates	158		118 (75%)		113 (72%)	
Ceratium		56		49		53
Dinophysis		19		13		10
Gonyaulax		6		5		4
Peridinium		35		26		28
oraminifera	25		21 (84%)		20 (80%)	
adiolarians	40		31 (78%)		21 (53%)	
intinnids	95		57 (60%)		64 (67%)	
Codonellopsis		5		2		3
Dictyocysta		8		5		6
Epiplocylis		6		1		3
Eutintinnus		10		7		9
Parundella		7		6		6
Rhabdonella		8		3		8
Salpingella		8		6		6
ther (see Table II and checklist)	10		7 (70%)		4 (40%)	
otal number of species	537					
otal number of co-occurring pecies			393 (73%)		385 (72%)	

*Percentages are only given for the number of species of South-West African higher taxonomic groups that also occur in the Mediterranean Sea and the South-West Indian Ocean

orids 10, and the rest three or fewer (see checklist d Table II).

Diatoms had the greatest species diversity i.e. 4 of which 27 were benthic. They were followed y dinoflagellates (158 species), tintinnids (95), diolarians (40), foraminifera (25), coccolitho- horids (15) and silicoflagellates (10). The re- aining groups numbered three species or fewer hecklist and Table II).

The small, unidentified flagellates seem to be bundant and to be important food organisms in ummer (e.g. January 1972) when thermoclines evelop and inshore waters tend to warm up (Sea isheries Institute, unpublished data for 1972).

South West African species in the Mediterranean Sea and the South-West Indian Ocean

Previously recorded presence or absence of South West African microplankton species in the Mediterranean Sea and the South-West Indian Ocean is indicated in the checklist. Frequency-of-occurrence of the species of the South West African microplankton taxa having five or more species per category is shown in Table III for the three areas. For genera with many species, the category was the genus, but otherwise it was a higher taxonomic group. Percentage frequency-of-occurrence is presented in Table III for higher

taxonomic groups only. The validity of the phytogeographic comparison depends mainly upon the intensity of sampling in the areas considered and the extent to which species were identified. Therefore, the findings of this comparative distribution study must be regarded as preliminary.

In respect of the frequency-of-occurrence of the species and the genera of the main taxa found off South West Africa, in the Mediterranean Sea and in the South-West Indian Ocean, some trends are evident from Table III and are therefore outlined.

Of the higher taxonomic groups, between 60 and 84 per cent of their species found off South West Africa also occur in the Mediterranean Sea. In respect of the species of each of the main genera, the variation is greater, e.g. all South West African *Nitzschia* species but less than half the species of the tintinnid genera *Codonellopsis*, *Epiplocylis* or *Rhabdonella* have been recorded in the Mediterranean Sea.

In the South-West Indian Ocean, 40—83 per cent of the South West African species of the higher taxonomic groups have been recorded. All the species of the diatom genera *Thalassiothrix* and *Nitzschia* and of the tintinnid genus *Rhabdonella* found in South West Africa have previously been recorded in the South-West Indian Ocean. Minimum representation in the South-West Indian Ocean by South West African species of the main genera was the 50-per-cent co-occurrence of the silicoflagellate *Dictyocha* and of the tintinnid *Epiplocylis*.

Of the 537 species identified in South West African waters in the present study, 393 (73 per cent) are shared with the Mediterranean Sea and 385 (72 per cent) with the South-West Indi Ocean. There is, however, a distinct possibil that further phytoplankton studies in all th areas considered may reveal even more spec common to them.

World distribution of South West African diato and dinoflagellates

The knowledge of presence or absence in oth parts of the world of microplankton species id tified in one area is important because of its use biogeographic and hydrographic species compa sons.

Global distribution of the South West Afric diatoms and dinoflagellates, as far as it could ascertained, is given in Table IV.

Over 46 per cent of the 184 identified Sou West African diatoms are cosmopolitan and alm 42 per cent are confined to tropico-tempera seas. Only 4 per cent are recorded as being fr tropical waters only. The remaining 8 per ce may be divided into those that have hitherto be recorded as being restricted to the west coast southern Africa, to the west and east coasts southern Africa, to the colder seas south of Afr and into a few species whose world distributio not known.

Diatoms display a low degree of endemicity South West Africa. Hart and Currie (1960) not that only *Delphineis karstenii, Fragilaria granula Chaetoceros strictus* and *C. tetras* are restrict to the Benguela Current and adjacent Sou African waters.

Fewer dinoflagellates than diatoms are cosm

Table IV: Assignment of South West African diatom and dinoflagellate species to areas in which they have be recorded in the literature (summarized from the checklist)

Area code*	Diatom species		Dinoflagellate species		Diatoms and dinoflagellates	
	Number	Percentage	Number	Percentage	Number	Percentage
c	85	46,2	38	24,1	123	35,9
tt	77	41,9	89	56,3	166	48,5
t	8	4,4	16	10,1	24	7,0
ws	4	2,2	1	0,6	5	1,5
wes	4	2,2	1	0,6	5	1,5
as	2	1,1	1	0,6	3	0,9
so	0	—	1	0,6	1	0,3
tl	0	—	1	0,6	1	0,3
ttl	0	—	4	2,5	4	1,2
z	4	2,2	6	3,8	10	2,9
Total	184		158		342	

* The explanation of these codes is given on p. 34.

litan but more are of tropico-temperate origin
ore than 24 per cent and 56 per cent respectively
a total of 158 species). Ten per cent of the
oflagellates found off South West Africa have
en classified as tropical. The remaining 9 per
t are representative of all the other areas,
ugh for almost 4 per cent, no world distribution
nown.
Of the 342 species of diatoms and dinoflagellates
nd off South West Africa, 36 per cent are
smopolitan, 48 per cent tropico-temperate and
per cent tropical. A mere 6 per cent have
viously been recorded as being restricted to
er waters adjacent to and south of southern
rica and the tropical and tropico-temperate
lantic. The remaining 3 per cent are of unknown
triction.

DISCUSSION

A total of 537 microplankton species have here
en distinguished. Nel (1968) listed 703 phyto-
nkton species as occurring in the South-West
dian Ocean, Travers and Travers (1975) found
out 700 in the Gulf of Marseilles and Tregouboff
d Rose (1957) more than 820 in the Mediter-
ean Sea.
During this study, diatoms were the dominant
up with 61 genera and 184 species. Travers
d Travers (1975) identified 62 diatom genera in
Gulf of Marseilles, and Taylor (1967) 59 in the
uth-West Indian Ocean. The next most impor-
t groups numerically in South West Africa
re the dinoflagellates with 34 genera and 158
cies and the tintinnids with 34 genera and 95
cies. By comparison, Travers and Travers *(op.*
) identified 33 dinoflagellate genera in the Gulf
Marseilles, although Tregouboff and Rose (1957)
ed 74 genera of the same group for the whole
editerranean Sea. Many of these 74 have been
onomically revised since. Taylor (1967 and 1976)
ntified about 35 dinoflagellate genera in the
uth-West Indian Ocean.
Despite the differences in the number of genera
d in the species diversity of the three areas
nsidered here, the diatoms, dinoflagellates, fora-
inifera and tintinnids of South West Africa had
similar proportional species representation in
th the Mediterranean Sea and the South-West
dian Ocean (see Table III). In contrast, although
uth West African coccolithophorids, radio-
ians, silicoflagellates and other groups were
ll represented in the Mediterranean Sea (67—78 per cent), they were not so common in the South-West Indian Ocean (40—53 per cent).

Species found off South West Africa have also been identified in other parts of Africa. For example, 76 and 70 per cent respectively of the South West African diatoms and dinoflagellates inhabit the Mozambique Channel (Sournia 1970) and 77 and 79 per cent respectively have been identified off Angola (Silva 1953, 1955 and 1957).

Many of the South West African diatom and dinoflagellate species occur in more distant parts of the world, e.g. 91 per cent of the South West African species of the dinoflagellate *Ceratium* have also been recorded in the South Pacific Ocean (Steemann-Nielsen 1934). Sournia (1970) stated that, of 288 species of diatoms and dinoflagellates he recorded from the Mozambique Channel, 255 (89 per cent) were cosmopolitan, tropical or temperate-tropical. This proportion is remarkably similar to that found off South West Africa in the present study (91 per cent), suggesting a great similarity between phytoplankton species in the world's oceans. Also, Hart and Currie (1960) listed 44 of the abundant or typical Benguela Current diatom species and showed that many of them commonly occur in 14 different oceanographic regions.

It has been stated that certain diatoms are more or less endemic, being restricted to the Benguela Current and adjacent South African waters. Sournia (1970) stated that certain species had hitherto been reported only from the Indian Ocean or Indo-Pacific, but could also be considered as "insufficiently known" species. Three of these species, i.e. the diatom *Bacteriastrum varians* and the dinoflagellates *Ceratium deflexum* and *Dinophysis miles* have now been found in the Atlantic Ocean and may be present in other areas too; the others, i.e. the diatoms *Actinoptychus trilingulatus, Campylodiscus biangulatus, Chaetoceros denticulatum, C. laeve, Detonula mooseleyana, Fragilaria aurivillii, Hemiaulus indicus, Licmophora aurivillii, Rhizosolenia clevei* and the dinoflagellate *Ceratium dens* may still be restricted to the Indian Ocean or Indo-Pacific only.

Most species have eurythermal, euryhaline and eurychemical qualities and could, therefore, occur in many parts of the world. Each ocean has its colder and warmer water areas, each with distinct hydrological affinities. Interactions between these water masses will result in the transport of phytoplankton species and their production stages from one area into another. Although the rate of this transport process may vary because of numerous mixing systems present at the interfaces between the areas, phytoplankton species have developed

either into those that can adapt themselves to variable conditions or into those that can only survive in certain areas or in a specific area.

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CHECKLIST OF SOUTH WEST AFRICAN MARINE PHYTOPLANKTON
(an explanation of the abbreviations and codes is given on p. 34)

KINGDOM: PLANTAE

DIVISION: CYANOPHYTA (BLUE-GREEN ALGAE)

CLASS: CYANOPHYCEAE

	Med.	*S.W.I.O.*
Oscillatoria hildebrandtii (Gomont) Geitler	−	+
O. thiebautii (Gomont) Geitler	+	+

DIVISION: CHLOROPHYTA (GREEN ALGAE)

CLASS: PRASINOPHYCEAE

Halosphaera viridus Schmitz	+	+
Trochischia brachiolata (Möb.) Lemm.	+	−
T. multispinosa (Möb.) Lemm.	−	−

DIVISION: EUGLENOPHYTA (EUGLENOIDS)

CLASS: EUGLENOPHYCEAE

Eutreptiella sp.	+	−

DIVISION: XANTHOPHYTA (YELLOW-GREEN ALGAE)

CLASS: XANTHOPHYCEAE

Solenicola setigera Pavill.	+	+

DIVISION: BACILLARIOPHYTA (DIATOMS)

CLASS: BACILLARIOPHYCEAE

	Bent.	Med.	S.W.I.O.	World
Achnanthes longipes Ag.	×	+	+	c
Actinocyclus octonarius Ehr.	×	+	+	c
Actinoptychus senarius (Ehr.) Ehr.	×	+	+	c
A. splendens (Shadb.) Ralfs	×	+	+	c
Amphora sp.		+	+	z
Arachnoidiscus ehrenbergii Bail.	×	−	−	tt
Asterionella japonica Cleve		+	+	c
Asterolampra marylandica Ehr.		+	+	tt
Asteromphalus flabellatus (Bréb.) Grev.	×	+	+	tt
A. heptactis (Bréb.) Ralfs		+	+	c
A. stellaris Br. & T.		−	+	c?
Auliscus sculptus (W. Sm.) Ralfs	×	+	−	tt?
Bacillaria paxillifer (Müll.) Hendey		+	+	c
Bacteriastrum comosum Pav.		+	+	tt?
B. delicatulum Cleve		+	+	tt
B. elegans Pav.		+	−	tt
B. elongatum Cleve		+	+	tt
B. hyalinum Laud.		+	+	tt
B. hyalinum var. *princeps* (Castr.) Ikari		+	+	tt
B. minus Karst.		−	+	tt
B. varians Laud.		−	+	tt?
Bacteriosira fragilis Gran		−	−	c?
Bellerochea indica Karst.		−	+	tt?
Biddulphia alternans (Bail.) V. H.		+	+	tt?
B. antediluviana (Ehr.) V. H. f. *antediluviana*	×	+	−	tt?
B. antediluviana f. *pentagona* (Péra.) Hendey	×	+	−	tt?
B. aurita (Lyngb.) Bréb. & God.	×	+	+	c
B. longicruris Grev.		−	+	tt
B. mobiliensis (Bail.) Grun.		+	+	tt
B. regia (Schultze) Ost.		+	+	tt?
B. tridens (Ehr.) Ehr.	×	+	+	t
Cerataulina pelagica (Cleve) Hendey		+	+	c
Chaetoceros aequatoriale Cleve		−	+	tt?
C. affinis Laud.		+	+	c
C. affinis var. *circinalis* (Meun.) Hust.		+	+	c
C. anastomosans Grun.		+	+	tt?
C. atlanticus Cleve		+	+	c
C. atlanticus var. *neapolitana* (Schröd.) Hust.		+	+	c
C. atlanticus var. *skeleton* (Schütt) Hust.		+	+	c
C. borealis Bail.		+	+	tt?
C. brevis Schütt		+	+	tt
C. compressus Laud.		+	+	c
C. constrictus Gran		+	+	c
C. convolutus Castr.		+	+	c
C. costatus Pav.		+	+	tt
C. curvatus Castr.		−	−	tt?
C. curvisetus Cleve		+	+	c
C. dadayi Pav.		+	+	tt
C. danicus Cleve		+	+	c

	Bent.	Med.	S.W.I.O.	World
C. debilis Cleve		+	+	tt
C. decipiens Cleve		+	+	c
C. densus (Cleve) Cleve		+	+	tt?
C. diademus (Ehr.) Gran		+	+	tt
C. dichaeta Ehr.		+	+	c
C. didymus Ehr.		+	+	c
C. difficilis Cleve		+	+	tt?
C. holsaticus Schütt		+	+	c?
C. imbricatus Mang.		−	+	c?
C. laciniosus Schütt		+	+	tt
C. lorenzianus Grun.		+	+	tt
C. messanensis Castr.		+	+	tt
C. neogracilis van Landingham		+	+	tt?
C. parallelis Boden		−	+	c?
C. pendulus Karst.		+	+	c?
C. perpusillus Cleve		+	+	tt
C. peruvianus Brightw.		+	+	c
C. pseudocrinitus Ost.		+	+	tt
C. radicans Schütt		+	+	c?
C. rostratus Laud.		+	+	c
C. similis Cleve		−	−	c
C. simplex Ost.		+	−	c
C. socialis Laud.		+	+	c
C. strictus Karst.		−	−	ws
C. teres Cleve		+	+	tt
C. tetras Karst.		−	+	wes
C. tortissimus Gran		+	+	c
C. vanheurckii Gran		−	−	c?
C. vixvisibilis (Schill.) Hust.		−	−	tt?
Climacodium frauenfeldianum Grun.		+	+	tt
Corethron criophilum Castr.		+	+	c
Coscinodiscus africanus Jan.		+	+	c
C. centralis Ehr.		+	+	c
C. concinnus W. Sm.		+	+	tt
C. curvatulus Grun.		+	+	c
C. gigas Ehr.		+	+	tt
C. granii Gough		+	+	tt
C. janischii A. Schm.		+	−	t
C. lineatus Ehr.		+	+	c
C. oculus-iridus Ehr.		+	+	c
C. parvulus Karst.		−	−	ws
C. perforatus Ehr.		+	+	c
C. radiatus Ehr.		+	+	c
C. stellaris Rop.		+	+	tt
C. subtilis Ehr.		+	+	tt
Cyclotella comta (Ehr.) Kütz.		−	−	c
Dactyliosolen mediterraneus (Péra.) Péra.		+	+	tt
Delphineis karstenii (Boden) Fryxell		−	−	ws
Ditylum brightwellii (West.) Grun.		+	+	tt
Ethmodiscus gazellae (Jan.) Hust.		+	+	a?
Eucampia cornuta (Cleve) Grun.		−	+	t
E. zoodiacus Ehr.		+	+	c
Fragilaria granulata Karst.		−	−	ws
Gephyria gigantea Grev.		−	−	tt?

	Bent.	*Med.*	*S.W.I.O.*	*World*
Grammatophora angulosa Ehr.	×	+	+	tt
G. marina (Lyngb.) Kütz.	×	+	+	c
Guinardia blavyana Péra.		+	−	tt?
G. flaccida (Castr.) Péra.		+	+	c
Hemiaulus hauckii Grun.		+	+	tt
H. sinensis Grev.		+	+	t
Hemidiscus cuneiformis Wall.		+	+	c
Hyalodiscus parvulus Karst.		−	+	tt?
Lauderia annulata Cleve		+	+	c
Leptocylindrus danicus Cleve		+	+	c
L. minimus Gran		−	−	c
Licmophora lyngbeyi (Kütz.) Grun.	×	+	+	c
Mastogloia sp.	×	+	+	z
Melosira imbigua (Grun.) Müll.		+	−	tt?
M. moniliformis (Müll.) Ag.	×	+	−	tt?
M. sphaerica Karst.		−	−	tt?
Navicula corymbosa Ag.	×	−	−	t?
N. wawrikae Hust.		+	−	tt?
Nitzschia closterium (Ehr.) W. Sm.		+	+	c
N. delicatissima Cleve		+	+	c?
N. pacifica Cupp		+	+	c?
N. longissima (Bréb.) Ralfs		+	+	c
N. pungens Grun.		+	+	c?
N. seriata Cleve		+	+	c
Paralia sulcata (Ehr.) Cleve	×	+	+	c
Pinnularia divergens var. *paralella* (Brun) Patr.	×	−	−	tt?
Plagiogramma vanheurckii Grun.	×	+	+	tt
Planktoniella sol (Wall.) Schütt		+	+	t
P. formosa (Karst.) Karst.		−	+	as
Pleurosigma directum Grun.		−	+	c?
P. karstenii Taylor		−	+	wes
P. normanni Ralfs		+	+	c
Pseudoeunotia doliolus (Wall.) Grun.	×	−	+	tt
Rhizosolenia acuminata (Péra.) Grun.		+	+	tt
R. alata Brightw.		+	+	c
R. alata f *gracillima* (Cleve) Grun.		+	+	c
R. alata f. *indica* (Péra.) Ost.		+	+	c
R. bergonii Péra.		+	+	tt
R. calcar-avis Schultze		+	+	tt
R. castracanei Péra.		+	+	t
R. cylindrus Cleve		+	+	tt
R. delicatula Cleve		+	+	tt
R. fragilissima Berg.		+	+	c
R. hebetata f. *semispina* (Hen.) Gran		+	+	c
R. imbricata Brightw.		+	+	c
R. imbricata var. *shrubsolei* (Cleve) Schröd.		+	+	c
R. robusta Norm.		+	+	tt
R. setigera Brightw.		+	+	c
R. simplex Karst.		−	+	as
R. sp. (R. sp. "A" of Nel 1962)		−	+	wes
R. stolterfothii Péra.		+	+	c
R. styliformis Brightw.		+	+	c
R. styliformis var. *longispina* Hust.		+	+	c
Schröderella delicatula (Péra.) Pav.		+	+	c

	Bent.	Med.	S.W.I.O.	World
Skeletonema costatum (Grev.) Cleve		+	+	c
Stauroneis membranacea Cleve		+	+	tt
S. sp.	×	–	+	z
Stephanopyxis palmeriana (Grev.) Grun.		+	+	t
S. turris (Grev. & Arn.) Ralfs		–	+	tt
Streptotheca tamesis Schrubs.		+	+	tt
Striatella sp.	×	+	–	z
Surirella fastuosa var. *recedens* (A. Schm.) Cleve		+	–	tt
Synedra gaillonii (Bory) Ehr.	×	+	+	tt
Thalassionema nitzschioides (Grun.) Hust.		+	+	c
Thalassiosira aestivalis Gran & Angst.		–	–	tt
T. condensata Cleve		+	+	tt
T. decipiens (Grun.) Jörg.		+	+	c
T. eccentrica (Ehr.) Cleve		+	+	c
T. hyalina (Grun.) Gran		+	–	c?
T. polychorda (Gran) Lavr.		+	+	c
T. rotula Meun.		+	+	tt
T. subtilis (Ost.) Gran		+	+	c
Thalassiothrix acuta Karst.		–	+	wes
T. antarctica var. *echinata* Karst.		–	+	tt
T. delicatula Cupp		–	+	tt?
T. frauenfeldii (Grun.) Cleve & Möll.		+	+	c
T. heteromorpha Karst.		+	+	tt
T. longissima Cleve & Grun.		+	+	c
Triceratium favus Ehr.	×	–	+	tt
T. pentacrinus f. *quadrata* Hust.	×	–	–	tt
Tropidoneis elegans W. Sm.	×	–	–	c

DIVISION: CHRYSOPHYTA (GOLDEN-BROWN ALGAE)

CLASS: CHRYSOPHYCEAE

ORDER: CHRYSOMONADALES

Sub-order: Silicoflagellineae (silicoflagellates)

	Med.	S.W.I.O.
Cannopilus sp.	+	–
Dictyocha fibula Ehr.	+	+
D. fibula var. messanensis (Haeck.) Lemm.	+	+
D. octonaria Ehr.	+	+
D. speculum var. *polyactis* (Ehr.) Lemm.	+	–
D. speculum var. *regularis* (Ehr.) Lemm.	+	–
D. speculum var. *septenarius* (Ehr.) Lemm.	+	+
D. staurodon Ehr.	–	–
D. triacantha Ehr.	–	–
Mesocena polymorpha f. *octonaria* Schulz	–	+

CLASS: HAPTOPHYCEAE (GOLDEN-BROWN ALGAE)

ORDER: PRYMNESIALES

Family: Phaeocystaceae

	Med.	*S.W.I.O.*
Phaeocystis sp.		

Family: Coccolithaceae (coccolithophorids)

Calciosolenia granii Schill.	−	+
Calyptrosphaera oblonga Lohm.	+	−
C. quadridentata Schill.	+	−
Coccolithus huxleyi (Lohm.) Kamptner	+	+
Cyclococcolithus fragilis (Lohm.) Deflandre	+	+
C. leptoporus (Murr. & Blackm.) Kamptner	+	+
Deutschlandia anthos Lohm.	−	−
Discosphaera tubifera (Murr. & Blackm.) Ost.	+	+
Haplopappus adriaticus Schill.	−	−
Rhabdosphaera longistylis Schill.	−	−
Syracosphaera dentata Lohm.	+	−
S. grundii Schill.	−	−
S. mediterranea Lohm.	+	−
S. pulchra Lohm.	+	+
Umbilicosphaera sibogae (Weber-van Bosse) Gaarder	+	−

DIVISION: PYRRHOPHYTA (DINOFLAGELLATES)

CLASS: DESMOPHYCEAE

	Med.	*S.W.I.O.*	*World*
Mesoporos perforatus (Gran) Lillick.	+	−	tt
Prorocentrum balticum (Lohm.) Abé	+	−	tt
P. micans Ehr.	+	+	c
P. hentscheli Schill.	+	+	ttl?

CLASS: DINOPHYCEAE

Amphidinium sp.	+	−	z
Amphidoma nucula Stein	−	−	so?
Amphisolenia bidentata Schröd.	+	+	t
A. bispinosa Kof.	−	−	t
A. globifera Stein	+	+	t
A. quadrispina Kof.	−	−	tt?
Blastodinium mangini Chatton	+	−	c
Brachydinium taylorii Sournia	−	−	wes
Centrodinium biconicum (Murr. & Whitt.) Taylor	−	−	tl?
Ceratium arietinum Cleve var. *arietinum*	+	+	tt
C. arietinum var. *bucephalum* (Cleve) Sournia	−	+	tt
C. arietinum f. *gracilentum* (Jörg.) Sournia	+	+	tt
C. azoricum Cleve	+	+	tt
C. biceps Clap. & Lachm.	+	+	tt

	Med.	S.W.I.O.	World
C. breve (Ost. & Schm.) Schröd.	–	+	t
C. candelabrum (Ehr.) Stein	+	+	tt
C. candelabrum (Ehr.) Stein var. *candelabrum*	+	+	tt
C. candelabrum f. *depressum* (Pouch.) Jörg.	+	+	tt
C. carriense Gourr.	+	+	tt
C. carriense var. *volans* (Cleve) Jörg.	+	+	tt
C. concilians Jörg.	+	+	tt
C. contortum (Gourr.) Cleve	+	–	t
C. contrarium (Gourr.) Pav.	+	–	tt
C. declinatum (Karst.) Jörg.	+	+	tt
C. deflexum (Kof.) Jörg.	+	+	tt
C. extensum (Gourr.) Cleve	+	+	tt
C. falcaticorme Jörg.	+	+	tt
C. furca (Ehr.) Clap. & Lachm. var. *furca*	+	+	c
C. furca f. *corpulentum* Jörg.	+	+	c
C. fusus (Ehr.) Dujard.	+	+	c
C. fusus var. *schüttii* Lemm.	+	+	c
C. fusus var. *seta* (Ehr.) Sournia	+	+	c
C. gibberum Gourr.	+	+	tt
C. gibberum var. *dispar* (Pouch.) Sournia	+	+	tt
C. gibberum var. *subaequale* Jörg.	+	+	tt
C. gravidum Gourr.	+	+	tt
C. hexacanthum Gourr.	+	+	tt
C. hexacanthum var. *contortum* Lemm.	+	+	tt
C. horridum (Cleve) Gran	+	+	c
C. horridum var. *buceros* (Zacch.) Sournia	+	+	c
C. horridum (Cleve) Gran var. *horridum*	–	+	c
C. horridum f. *claviger* (Kof.) Sournia	+	+	c
C. incisum (Karst.) Jörg.	+	+	t
C. kofoidii Jörg.	+	+	t
C. lineatum (Ehr.) Cleve	–	+	as?
C. longipes (Bail.) Gran	–	+	c?
C. lunula (Schm. ex Karst.) Jörg.	+	+	tt
C. macroceros (Ehr.) Vanhöff.	+	+	tt
C. macroceros var. *gallicum* (Kof.) Sournia	+	–	tt
C. massiliense var. *protuberans* (Karst.) Jörg.	+	+	tt
C. massiliense f. *armatum* (Karst.) Jörg.	+	+	tt
C. minitum Jörg.	+	+	tt?
C. paradoxides Cleve	–	+	t
C. pentagonum Gourr.	+	+	c
C. pentagonum var. *robustum* (Cleve) Jörg.	+	+	c
C. pentagonum var. *tenerum* Jörg.	+	+	c
C. platycorne Daday	+	+	c
C. setaceum Jörg.	+	+	tt
C. symmetricum Pav.	+	+	tt
C. trichoceros (Ehr.) Kof.	+	+	t
C. tripos (Müll.) Nitzsch	+	+	c
C. tripos var. *balticum* Schütt	+	+	c
C. tripos var. *ponticum* Jörg.	+	+	c
C. tripos var. *pulchellum* (Schröd.) Lopez	+	+	c
C. vultur Cleve	–	+	t
Ceratocorys horrida Stein	+	+	tt
Cladopyxis brachiolata Stein	+	+	tt
C. setifera Lohm.	–	–	tt

	Med.	S.W.I.O.	World
Cochlodinium adriaticum Schill.	+	−	tt?
Cystodinium sp.	−	−	z
Dinophysis acuminata Clap. & Lachm.	−	+	tt
D. argus (Stein) Balech	+	−	tt
D. cuneus (Schütt) Balech	+	+	tt
D. curvata Schill.	−	−	ttl?
D. fortii Pav.	+	+	tt
D. lens (Kof. & Skbg.) Balech	−	−	tt
D. minuta (Cleve) Balech	−	+	tt
D. ovum (Schütt) Balech	+	−	tt
D. parvula (Schütt) Balech	+	−	tt
D. punctata Jörg.	+	−	tt
D. recurva Kof. & Skbg.	+	+	tt
D. rotundatum (Clap. & Lachm.) Kof. & Mich.	+	+	tt
D. rotundatum var. *laevis* (Clap. & Lachm.) Jörg.	−	−	tt
D. sacculus Stein	+	−	c
D. schröderi Pav.	−	−	tt
D. schüttii Murr. & Whitt.	+	+	t
D. sphaerica Stein	+	+	c?
D. tripos Gourr.	+	+	tt
D. whittingae Balech	−	+	tt
Diplopsalis lenticula Bergh	+	+	c
Dissodinium gerbaulti (Pav.) Taylor	+	−	t
D. lunula (Schütt) Pasch.	+	+	c
Gonyaulax africana Schill.	+	−	ttl
G. minuta Kof. & Mich.	+	+	tt
G. polyedra Stein	+	+	tt
G. polygramma Stein	+	+	c?
G. spinifera (Clap. & Lachm.) Diesing	+	+	c?
G. tamarensis Leb.	−	−	tt
Gymnodinium albulum Lind.	−	−	z
G. galatheanum Braarud	−	−	ws
G. galeaeforme Matz.	−	−	tt
G. uberrimum (Allm.) Kof. & Sw.	−	+	tt?
Gyrodinium fulvum Kof. & Sw.	−	−	tt?
Heteraulacus polyedricus (Pouch.) Drugg & Loeblich	+	+	c?
Heterodinium mediterraneum Pav.	+	−	tt
Noctiluca scintillans (Macart.) Ehr.	+	+	c
Ornithoceros magnificus Stein	+	+	tt
Oxytoxum scolopax Stein	+	+	t
Palaeophalacroma verrucosum Schill.	−	−	tt?
Peridinium breve (Pauls.) Pauls.	+	+	tt?
P. brochii Kof. & Sw.	+	+	tt
P. cerasus Pauls.	+	+	tt
P. claudicans Pauls.	+	+	tt
P. conicum (Gran) Ost. & Schm.	+	+	c
P. crassipes Kof.	+	+	tt
P. decipiens Jörg.	−	+	c?
P. depressum Bail.	+	+	c
P. diabolus Cleve	+	+	tt
P. divergens Ehr.	+	+	tt
P. elegans Cleve	−	+	tt
P. globulus Stein	+	+	tt
P. grande Kof.	+	+	tt

	Med.	S.W.I.O.	World
P. granii (Ost.) Pauls.	+	+	tt
P. latissimum Kof.	–	+	tt
P. leonis Pav.	+	+	tt
P. leonis f. *matzenaueri* Schill.	–	–	tt
P. longicollum Pav.	+	–	tt
P. mite Pav.	+	+	tt
P. monacanthum Broch.	–	+	c?
P. oceanicum Vanhöff.	+	+	c
P. pallidum Ost.	+	+	c
P. pendunculatum Schütt	+	+	tt
P. pellucidum (Bergh) Schütt.	+	+	c
P. pentagonum Gran	+	+	tt
P. pyriforme Pauls.	+	+	c?
P. solidicorne Mang.	+	+	c?
P. steinii Jörg.	+	+	tt
P. subpyriforme Dangeard	–	–	tt
P. tenuissimum Kof.	+	+	tt
P. triquetrum (Ehr.) Leb.	–	–	ttl?
P. tristylum Stein	+	+	tt
P. trochoideum (Stein) Lemm.	+	–	tt?
P. variegatum Peters	–	–	n
P. wiesneri Schill.	–	–	tt?
Podolampas palmipes Stein	+	+	tt
P. spinifera Okamura	+	+	tt
Pronoctiluca peridinioides Schill.	–	–	tt?
Pyrocystis noctiluca Schütt	+	+	t
P. robusta Kof.	–	+	t
Pyrodinium sp.	+	–	z
Pyrophagus horologium Stein	+	+	tt
Sphaerodinium sp.	–	–	z
Triposolenia bicornis Kof.	+	+	t
Warnowia sp.	+	–	z

KINGDOM: ANIMALIA

PHYLUM: PROTOZOA

CLASS: RHIZOPODEA

ORDER: FORAMINIFERIDA (FORAMINIFERA)

	Med.	S.W.I.O.
Ammodiscus sp.	–	+
Ammonia beccarii (Linné)	+	–
Bifarina saxipara (Ehr.)	–	–
Bolivina spathulata Williamson	+	+
B. sp.	+	+
Bulimina marginata d'Orb.	+	+
Elphidium cf. *advenum* Cushman	–	–

	Med.	S.W.I.O.
Globigerina bulloides d'Orb.	+	+
G. quinqueloba Natland	+	+
Globigerinella aequilateralis (Brady)	+	+
Globigerinoides sacculifer (Brady)	+	+
Globoquadrina dutertrei (d'Orb.)	+	+
Globorotalia inflata (d'Orb.)	+	+
G. menardii (d'Orb.)	+	+
G. scitula (Brady)	+	–
G. truncatulinoides (d'Orb.)	+	+
Hastigerina sp.	+	+
Haylinea balthica (Schroeter)	–	–
Lagena sp.	+	+
Nodosaria sp.	+	+
Orbulina bilobata (d'Orb.) Blow	+	+
D. universa d'Orb.	+	+
Saccamina minuta Rhumbler	+	+
Textularia sp.	+	+
Uvigerina sp.	+	+

ORDER: RADIOLARIA

Acanthocorys umbellifera Haeck.	+	+
Acanthonidium sp.	+	+
Arachnocorys circumstexta Haeck.	+	–
A. sp.	–	–
Aulosphaera sp.	+	+
Cannosphaera geometrica Borgert	–	–
Cementella loricata Borgert	+	–
Challengeron armatum Borgert	+	+
Circoporus sexfuscinus Haeck.	+	+
Clathrocyclas coscinodiscus Haeck.	–	+
Conacon foliaceus Haeck.	+	–
Corocalyptra craspedota Jörg.	–	+
C. elisabethae Haeck.	+	+
C. emmae Haeck.	+	–
Dictyoceras virchowii Haeck.	+	–
Dictyophimus brandtii Haeck.	–	–
D. platycephalus Haeck.	+	–
D. tripus Haeck.	+	–
D. sp.	–	–
Eucecryphalus gegenbauri Haeck.	+	+
Heliosphaera echinoides Haeck.	+	–
Hexacontium asteracanthion Haeck.	+	+
H. enthacanthum Jörg.	+	+
Hexalonche sp.	+	+
Lamprodiscus laevis Hertw.	+	–
Lithomelissa thoracites Haeck.	+	+
Medusetta arcifera Jörg.	–	–
M. armata Borgert	+	–
M. partenopaea Borgert	+	–
Nephrospyris renilla Haeck.	+	–
Phormacantha hystrix Jörg.	–	–
Protocystis xiphodon (Haeck.)	+	+

	Med.	S.W.I.O.
Pterocorys carinata Haeck.	+	+
Pteroscenium sp.	+	+
Rhizosphaera trigonacantha Haeck.	+	+
Sagena tenaria Haeck.	+	+
Sagoscena gracilis Haeck.	+	–
Sticholonche zanclea Hertw.	+	+
Thecosphaera inermis Haeck.	+	+
Xanthiosphaera erinacea Haeck.	–	+

CLASS: CILIATEA

ORDER: TINTINNIDA

Acanthostomella conicoides Kof. & Camp.	+	–
Amphorellopsis laevis Kof. & Camp.	–	–
Amphorides calida (Kof. & Camp.) Strand	–	–
Ascampbelliella acuta (Kof. & Camp.) Corliss	+	–
Cantharíella sp.	+	+
Climacocylis scalaria (Bdt.) Jörg.	+	+
Codonella elongata Kof. & Camp.	+	+
C. galea Haeck.	+	+
C. saccus Kof. & Camp.	–	+
Codonellopsis contracta Kof. & Camp.	–	+
C. orthoceras (Haeck.) Jörg.	+	–
C. ovata Jörg.	–	–
C. pusilla (Cleve) Kof. & Camp.	–	+
C. tuberculata (Daday) Jörg.	+	+
Coxliella fasciata (Kof.) Bdt.	+	+
Cymatocylis sp.	–	+
Cyttarocylis sp.	–	+
Dadayiella acuta (Jörg.) Kof. & Camp.	+	+
D. bulbosa (Bdt.) Kof. & Camp.	–	–
D. jörgensenii Kof. & Camp.	–	+
Dictyocysta ampla Kof. & Camp.	+	+
D. dilatata Bdt.	+	+
D. elegans Ehr.	+	+
D. grandis Bdt.	–	+
D. magna Kof. & Camp.	–	–
D. mülleri (Imhof) Jörg.	+	+
D. nidulus Kof. & Camp.	–	+
D. speciosa Jörg.	+	–
Epicranella sp.	–	–
Epiplocylis acuminata (Daday) Jörg.	+	–
E. bruhni (Bdt.) Jörg.	–	+
E. constricta Kof. & Camp.	–	–
E. inflata Kof. & Camp.	–	–
E. laackmanni Kof. & Camp.	–	+
E. lineata Kof. & Camp.	–	+
Eutintinnus apertus (Kof. & Camp.) Kof. & Camp.	+	+
E. fraknoii (Daday) Kof. & Camp.	+	+
E. latus (Jörg.) Kof. Camp.	+	+

	Med.	*S.W.I.O.*
E. lusus-undae (Entz) Kof. & Camp.	+	–
E. macilentus (Jörg.) Kof. & Camp.	+	+
E. medius (Kof. & Camp.) Kof. & Camp.	–	+
E. pinguis (Kof. & Camp.) Kof. & Camp.	–	+
E. stramentus (Kof. & Camp.) Kof. Camp.	+	+
E. tenue (Kof. & Camp.) Kof. & Camp.	–	+
E. tubulosus (Ost.) Kof. & Camp.	+	+
Favella arcuata (Bdt.) Jörg.	–	–
F. attingata Kof. & Camp.	+	–
F. ehrenbergii (Clap. & Lachm.) Jörg.	+	–
F. serrata (Möb.)	+	–
Helicostomella subulata (Ehr.) Jörg.	+	–
Metacylis corbula Kof. & Camp.	–	–
M. jörgensenii (Cleve) Kof. & Camp.	+	–
Parundella aculeata (Jörg.) Kof. & Camp.	+	+
P. attenuata Jörg.	+	–
P. caudata (Ost.) Kof. & Camp.	+	+
P. inflata Kof. & Camp.	–	+
P. lachmanni (Daday)	+	+
P. lohmanni Jörg.	+	+
P. longa Jörg.	+	+
Petalotricha ampulla (Fol) Kent	+	–
P. serrata Kof. & Camp.	–	+
Poroecus apiculatus (Cleve) Cleve	+	–
Proplectella ovata (Jörg.) Kof. & Camp.	+	+
P. pentagona (Jörg.) Kof. & Camp.	+	–
P. praelonga Kof. & Camp.	–	–
Protorhabdonella curta (Cleve) Jörg.	+	+
P. simplex (Cleve) Jörg.	+	+
Rhabdonella amor (Cleve) Bdt.	+	+
R. brandtii Kof. & Camp.	+	+
R. conica Kof. & Camp.	–	+
R. hebe Cleve	–	+
R. hensenii (Bdt.) Bdt.	–	+
R. lohmanni Kof. & Camp.	–	+
R. spiralis (Fol) Bdt.	+	+
R. torta Kof. & Camp.	–	+
Salpingacantha unguiculata (Bdt.) Kof. & Camp.	–	–
Salpingella acuminata (Clap. & Lachm.) Jörg.	+	+
S. attenuata Jörg.	+	+
S. decurtata Jörg.	+	+
S. glockentögeri (Bdt.) Kof. & Camp.	+	–
S. minutissima Kof. & Camp.	–	+
S. ricta Kof. & Camp.	–	+
S. rotundata Kof. & Camp.	+	–
S. subconica Kof. & Camp.	+	+
Steenstrupiella gracilis (Jörg.) Kof. & Camp.	+	–
S. steenstrupii (Clap. & Lachm.) Kof. & Camp.	+	+
Stenosemella oliva (Meunier)	+	+
Tintinnopsis beroidea Stein	+	–
T. cylindrica Daday	+	+
Xystonella lohmanni (Bdt.) Bdt.	+	–
X. minuscula Kof. & Camp.	–	+
X. treforti (Daday) Laack.	+	+

	Med.	*S.W.I.O.*
Xystonellopsis ornata (Bdt.) Kof. & Camp.	–	–
Undella ostenfeldii Kof. & Camp.	–	–
Undellopsis tricollaria (Laack.) Kof. & Camp.	+	–
ORDER: PERITRICHIDA		
Zoothamnium pelagicum du Plessis	+	–
ORDER: HOLOTRICHIDA		
Mesodinium rubrum (Lohm.)	+	–

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GENERAL DISTRIBUTION OF PELAGIC FISH OFF SOUTH WEST AFRICA AS DEDUCED FROM AERIAL FISH SPOTTING (1971—1974 AND 1977) AND AS INFLUENCED BY HYDROLOGY

J. J. AGENBAG

Positions of pelagic fish shoals were recorded by aerial fish-spotting surveys off the South West African coast during the years 1971—1974 and 1977. The parameter "frequency-of-occurrence", defined as the ratio of times fish occurred in a given geographical area to the number of times that area had been searched, was used to describe fish distribution for "summer" (October—March) and "winter" (April—September). The "winter" distribution pattern showed two areas with high frequency-of-occurrence values, one to the north of Cape Cross and the other to the south of Walvis Bay. During "summer", shoals occurred more evenly along the coast and, on average, also closer inshore than in "winter". These seasonal and regional differences are discussed in terms of general environmental conditions.

Die verspreiding van pelagiese vis aan die kus van Suidwes-Afrika is beskrvf aan die hand van gegewens oor skoolposisies verkry tydens visopsporingsvlugte wat van 1971 tot 1974 en in 1977 in daardie gebied uitgevoer is. Verspreidingspatrone vir "somer" (Oktober tot Maart) en "winter" (April tot September) word beskryf. Die beskrywings geskied deur middel van 'n "voorkomsfrekwensie", omskryf as die verhouding van die getal kere dat vis in 'n bepaalde geografiese gebied voorgekom het, tot die getal kere dat daardie gebied deursoek is. Die winterverspreidingspatroon toon twee gebiede met hoë voorkomsfrekwensies aan — een noord van die Kruiskaap, die ander suid van Walvisbaai. In die "somer" het die skole egaliger langs die kus voorgekom en gemiddeld ook nader daaraan as in die "winter". Hierdie seisoen- en gebiedsverskille word bespreek aan die hand van die algemene omgewingstoestande.

In August 1971 the Sea Fisheries Branch commenced an extensive programme of aerial fish-spotting research, the principal aim of which was to assist in giving rapid regular estimates of the stock size of the pilchard *Sardinops ocellata* in South West Africa. Stock estimation was based on synchronized air- and ship-borne observations; detailed descriptions of these methods have been given by Cram (1977). Therefore, only a brief summary of the aerial side of the operations will be given here.

Shoals were detected at night by means of the planktonic bioluminescence produced as a result of fish movement in the water. The presence of such luminescent areas was plotted on a chart along with the aircraft's track. Aerial surveys were carried out on regularly spaced search lines about 10 nautical miles apart. Shoals were usually found to be concentrated in groups and, once a group was located, a number of closely spaced lines were flown in order to obtain an estimate of its surface area. On completion of this exercise the original search pattern was resumed.

Surveys of this nature were carried out on a more or less monthly basis from August 1971 to April 1974 when the operation was suspended. In 1977 a series of research flights was carried out in January and February, and a commercial fish-spotter also operated full-time in South West Africa between March and August. The commercial operation differed from the research operation in that the target of the former was fish location and not quantification, but the techniques used were otherwise essentially the same. Therefore, for the purposes of this report — which is only concerned with shoal positions — data from the two sources have been combined.

METHODS AND DATA PROCESSING

Shoal positions were extracted in a manner similar to that used by Squire (1972). The track charts of the aircraft were overlaid with a grid pattern consisting of 1 × 1 nautical mile squares. Where the flight track passed through a square, the square was allocated one of the following codes:

1 = Unidentified fish
2 = Pilchard shoal
3 = Anchovy shoal
4 = Horse-mackerel (maasbanker) shoal
5 = Unidentified bioluminescence
6 = Birds (inactive) } Day spotting
7 = Birds (active) } data not included
8 = Seals
9 = No visible indications of fish

Commercial fish-spotters working in conjunction with catcher boats become experienced in identifying fish species according to the shape and behaviour of the shoal. In South West Africa, where the pelagic fish population is composed almost entirely of three species, pilchard, anchovy *Engraulis capensis* and horse mackerel *Trachurus trachurus,* characteristic luminescent shapes were associated with these species (Cram and Agenbag 1974), but in general the scientists who acted as fish-spotters never became sufficiently experienced to confidently identify all shoals.

In consequence, the survey method was adapted to include a chartered purse-seine vessel which provided identification of shoal composition through catches. However, a catcher was usually available only during the closed fishing season and even then not all shoals located by the aircraft could be sampled, the result being that most aerial observations were classified as "unidentified fish". In a broad, qualitative sense most identified shoals were pilchard with the remainder made up of about equal proportions anchovy and horse mackerel, but in this report no attempt has been made to differentiate between species. Treatment of the coded data was based upon a combination of codes 1, 2, 3 and 4 and will simply be referred to as "fish".

Although aerial fish-spotting surveys were conducted along the entire South West African coastline, by far the greatest number of flights were made between the latitudes of Rocky Point (19°S) and Hollams Bird Island (25°S). The number of surveys to the north and south of these latitudes and further off shore than 50 nautical miles was considered too small for meaningful interpretation and all data derived outside these limits were therefore excluded for this report. The area was divided into 60 blocks: 12 zones in the north-south direction bounded by full and half degrees of latitudes, with 5 blocks of 10 miles in east-west extent in each zone. Finally, for each block, the ratio of the number of times fish were located in that block to the number of times the block was surveyed was calculated. This ratio, expressed as a percentage and referred to as "frequency-of-fish-occurrence", is used in this report for the description and discussion of pelagic fish distributions.

By definition, a high frequency suggests a high probability of finding fish in a particular locality, though not necessarily a great quantity. In practice, a relationship between frequency and quantity would probably exist by virtue of the fact that large shoal groups are more readily detected than smaller ones. The relationship would, however, be weak because the surface area of the shoal group can be related to fish quantity only through knowledge of several other parameters (e.g. percentage cover, shoal depth and packing density). In later discussions on the subject of fish distributions, the parameter "frequency-of-occurrence" will be assumed to be essentially independent of quantity of fish. The observed frequency patterns would not, therefore, be significantly influenced by fishing activity because the latter would be expected to affect mainly the quantitative distribution.

Frequency distributions were calculated for two periods, "summer" and "winter". The "summer" period incorporated all data for the months October—March, whereas all data for the months April—September were used to obtain the "winter" distribution. A finer division into four seasons would have been desirable in so far as correlation with environmental conditions would be concerned, but it would have been statistically less effective as a consequence of the smaller number of flights. The two-period subdivision was therefore adopted in an attempt to illustrate general distribution patterns of pelagic fish shoals during periods that are considered to represent the South West African pelagic fishing season (March—August) and the closed fishing season. The closed season coincides with the main spawning period for the three major pelagic fish species.

After this subdivision into periods, certain blocks, especially those near the defined off-shore limit, were found to have been very sparsely surveyed and, therefore, as an arbitrary rule, all blocks with less than five observations were excluded from further analysis.

RESULTS

Geographical frequency distribution of fish shoals

Figures 1 and 2 show "winter" and "summer" distributions in terms of frequency-of-occurrence. The same information is also presented in graphical form in Figure 3 as a means of indicating the longshore variation in fish occurrence for distances of 0—10, 10—20, 20—30 and 30—40 miles from the coast. The graphs in Figures 4 and 5 illustrate the

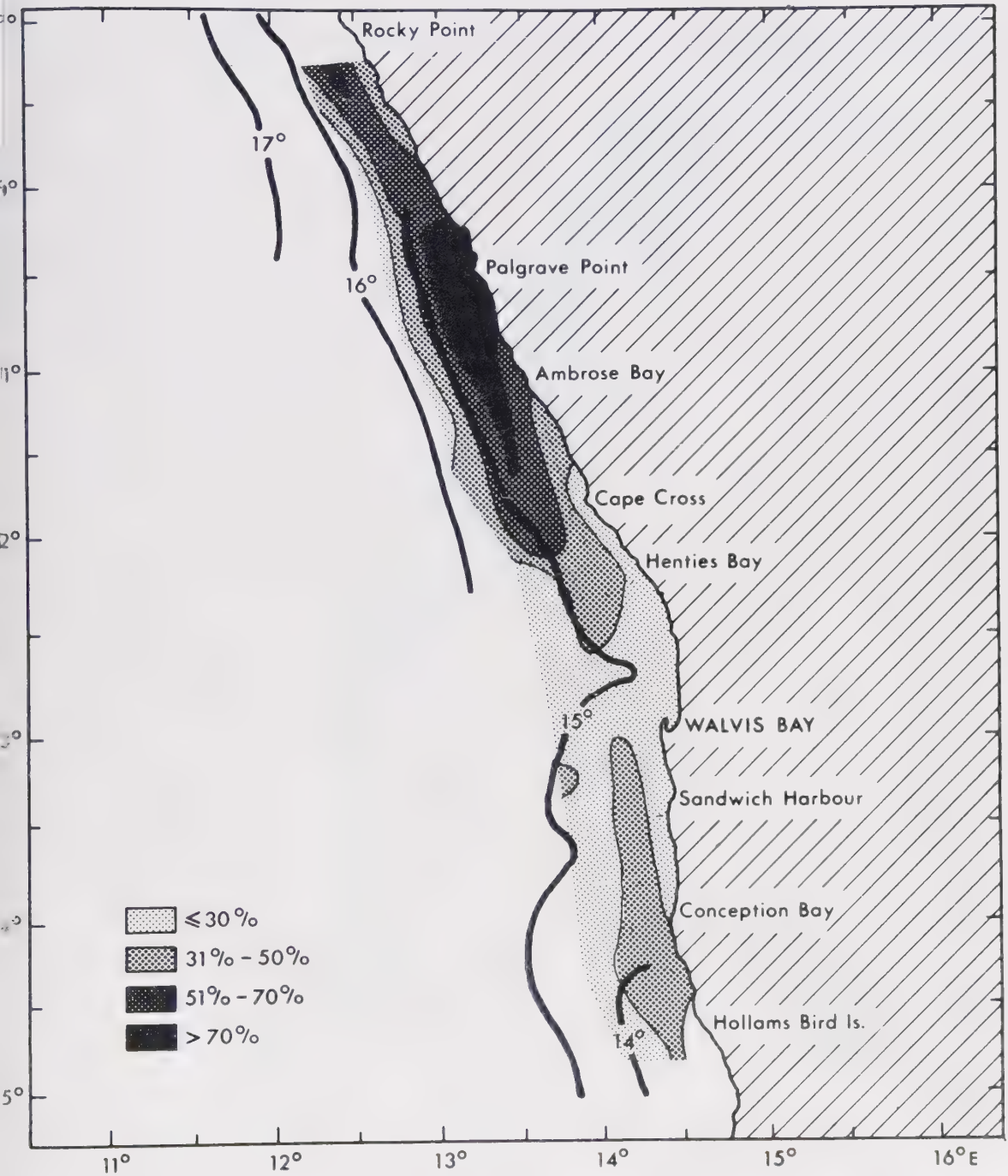

Fig. 1: Frequency-of-occurrence of pelagic fish with contours of mean surface temperature — "winter" period

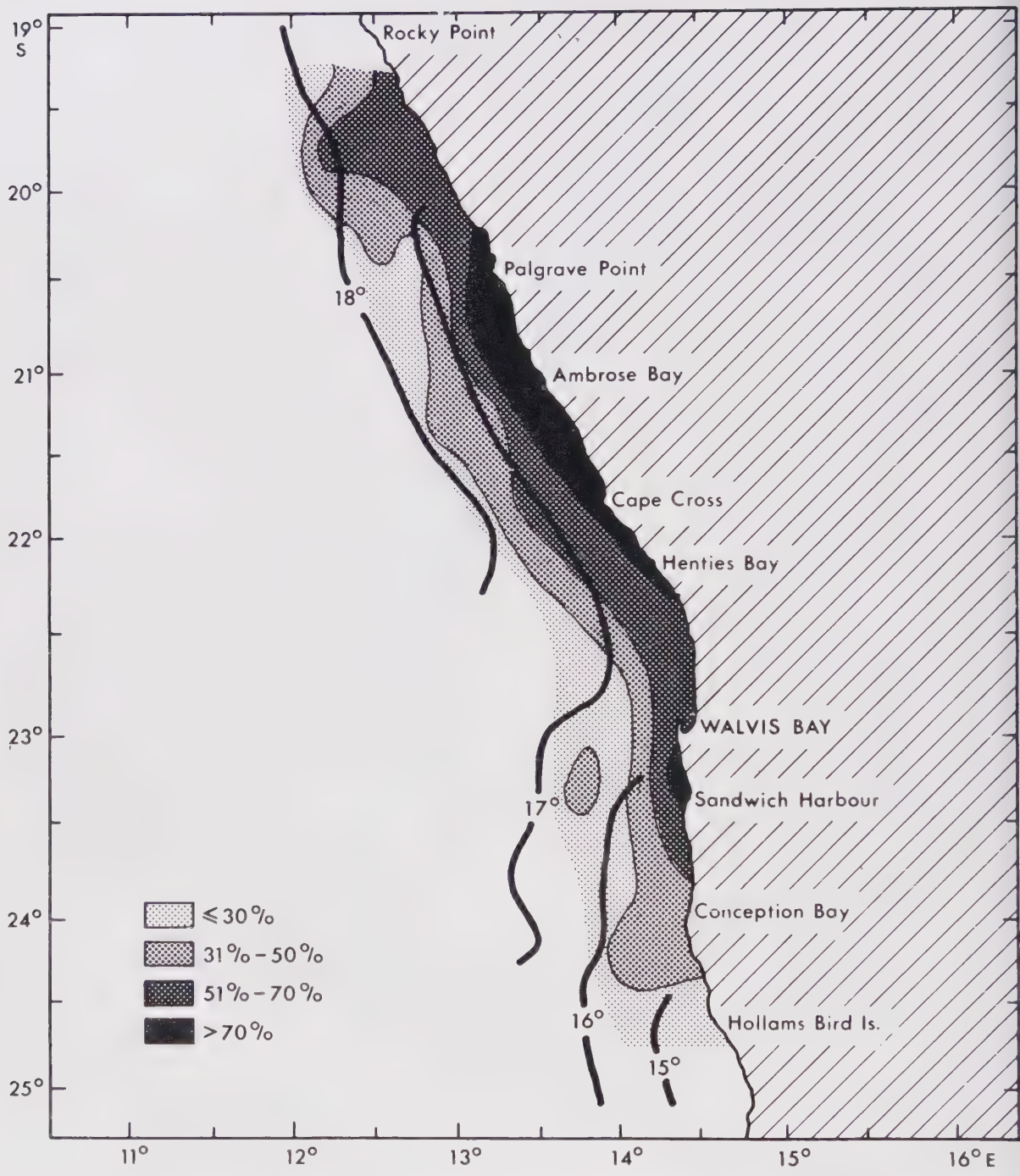

Fig. 2: Frequency-of-occurrence of pelagic fish with contours of mean surface temperature — "summer" period

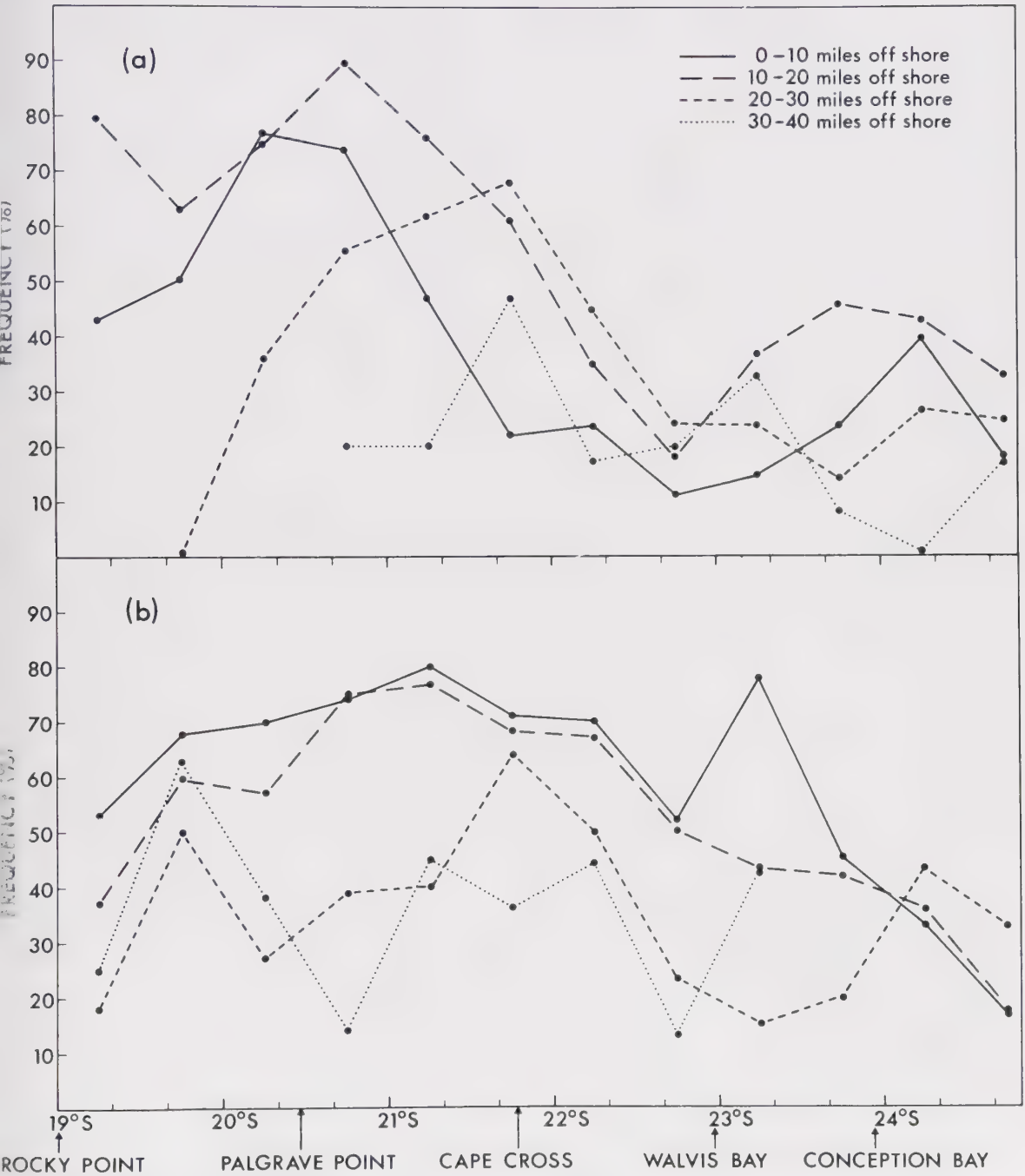

Fig. 3: Graphical representation of the long-shore fish distributions at successive intervals off shore — (a) "winter", (b) "summer"

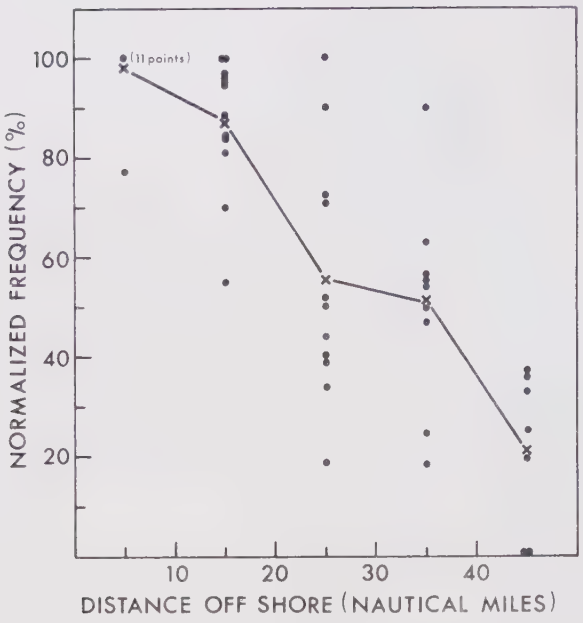

Fig. 4: Frequency-of-occurrence of pelagic fish in an off-shore direction — "summer" (frequencies in the east-west zone normalized to 100 per cent)

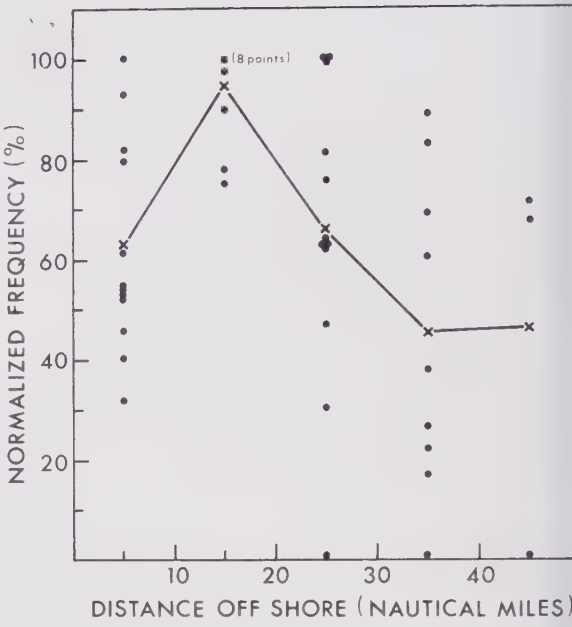

Fig. 5: Frequency-of-occurrence of pelagic fish in a off-shore direction — "winter" (frequencies in the east-west zone normalized to 100 per cent

relative frequency of fish occurrence in an off-shore direction and were drawn from frequency data in each of the 12 east-west zones after normalizing to 100 per cent. The following observations may be made from the results presented in the figures:

(i) For "summer", the long-shore 0—10 and 10—20 mile frequencies (Fig. 3b) appear as fairly smooth curves with a broad maximum centred at about 21°15′S (approximately opposite the Ugab River mouth). The sharp peak just south of Walvis Bay does not fit the trend and, because it is based on the value of one block only, it is somewhat suspect. There is, however, a suggestion of a local minimum in the region directly north of Walvis Bay (22°30′—23°S). Figure 2 also reflects this minimum.

(ii) The "winter" long-shore distribution curves (Fig. 3a) show two well-defined maxima. The highest frequency is in the 10—20 mile strip between 20°30′S and 21°S (i.e. between Palgrave Point and Ambrose Bay) and a secondary peak, also in the 10—20 mile strip, is between 23°30′S and 24°S (i.e. between Sandwich Harbour and Conception Bay). The curve designating the 0—10 mile long-shor strip follows the same general trend as that c the 10—20 mile strip, but without the clos agreement observed during "summer". In th 0—10 mile strip, maxima occur slightly nort and south of the main peaks in the 10—2 mile strip, i.e. between 20° and 20°30′S (Dun Point — Palgrave Point) and between 24 and 24°30′S (Conception Bay — Hollam Bird Island). The two maxima are separate by a clear minimum centred at about 22°45′S

(iii) During the "summer", shoals were most fre quently found close inshore (0—10 nautica miles) with an almost linear decrease in th off-shore direction (Fig. 4).

(iv) On average, shoals tended to be further o shore during the "winter" period and, althoug they were most frequently located betwee 10 and 20 miles from the shore, the mea frequency-of-occurrence was still slightly highe in the 20—30 mile strip than in the near-shor region (Fig. 5).

(v) A comparison of the curves for the successiv off-shore strips indicates that the norther

maximum shifted southwards with increasing distance from the shore, whereas in the south the opposite happened.

General frequency distribution and environmental conditions

Descriptions of the marine environment off South West Africa have been given by a number of authors (e.g. Stander 1964, Du Plessis 1967, O'Toole 1977) but, although it has been recognized that environmental conditions influence distribution and migration patterns of the pelagic fish, the actual interrelationship is not yet fully understood. De Vos and Visser (1972) stated that all commercially important fish species seem to prefer the cool, low salinity, oxygen-rich water. They further observed that, during 1971, no pelagic fish occurred in those regions where the surface temperature and salinity values were higher than 15,5°C and 35,45‰ respectively or the surface dissolved oxygen content less than 3,5 mℓ/ℓ. They concluded that oxygen was probably the limiting factor close inshore, whereas further off shore (more than 5 miles) temperature seemed to be the controlling feature.

Schülein (1972) observed that fish did not occur where the plankton layer, consisting of jelly fish, euphausiids and gobies was dense. Visser *et al.* (1973) found that pelagic fish off South West Africa occurred mainly in the so-called "intermediate zone" between the inshore dense phytoplankton and the off-shore dense zooplankton. They also noted that dense concentrations of phytoplankton are often associated with very low oxygen values, a factor which may also be responsible for the absence of fish from such areas. This observation agrees with that of Boney (1975), who noted that herring shoals seemed to avoid dense patches of phytoplankton.

Distribution of fish in the off-shore direction

On average, shoals occurred further off shore during "winter" than in "summer" (Figs. 4 and 5). This finding would be anticipated from the general hydrological conditions encountered in the area. The "summer" period represents a time of year during which upwelling decreases and vertical stabilization sets in. During "winter", upwelling increases in intensity to reach a maximum towards the end of the period (Stander 1964). Upwelling brings cold water to the surface along the coast, the water being of low dissolved oxygen concentration but high inorganic nutrient content. The high nutrient level gives rise to dense concentrations of phytoplankton species such as *Delphineis karstenii* (previously known as *Fragilaria karstenii)* and *Chaetoceros* spp., which occur in a belt associated with low oxygen content along the coast (Cram and Visser 1972). Figure 6 shows one example of winter phytoplankton distribution.

As upwelling diminishes in summer, nitrate and phosphate levels drop and conditions become less favourable for phytoplankton growth. The wide belt of dense phytoplankton which existed during the winter can, therefore, be expected to decrease in density and off-shore extent. The highest concentrations, however, can still be expected to occur near shore, as illustrated by Figure 7. Fish shoals which moved away from the coast during the winter would tend to follow the receding intermediate zone to occupy, on average, a position closer inshore. Conceivably, plankton density may drop to a level where the intermediate-zone concept no longer applies, in which case the fish will presumably inhabit the region which offers the most abundant food supply, i.e. the inshore zone.

In the following section, reason is given why the off-shore frequency distribution cannot, in fact, be discussed in isolation from the long-shore conditions. However, as a broad generalization, the findings of previous researchers about plankton distribution provide a reasonable basis for understanding the differences indicated by Figures 4 and 5.

Distribution of fish in the long-shore direction

Comparison of Figures 3a and 3b identifies the main difference between "summer" and "winter" long-shore distributions as a marked "winter" minimum between Cape Cross and Walvis Bay. This feature is largely absent from the "summer" distribution curves. The conclusion may be drawn that conditions in that area are unfavourable and particularly so during the "winter".

In comparison with other parts of the South West African coast, the region between Walvis Bay and Cape Cross has been studied reasonably well, and a fair amount of information is available on the local oceanographic conditions. From this information, three features appear to be noteworthy.

(i) Du Plessis (1967) demonstrated the probability of a strong thermocline in the area. In Figure

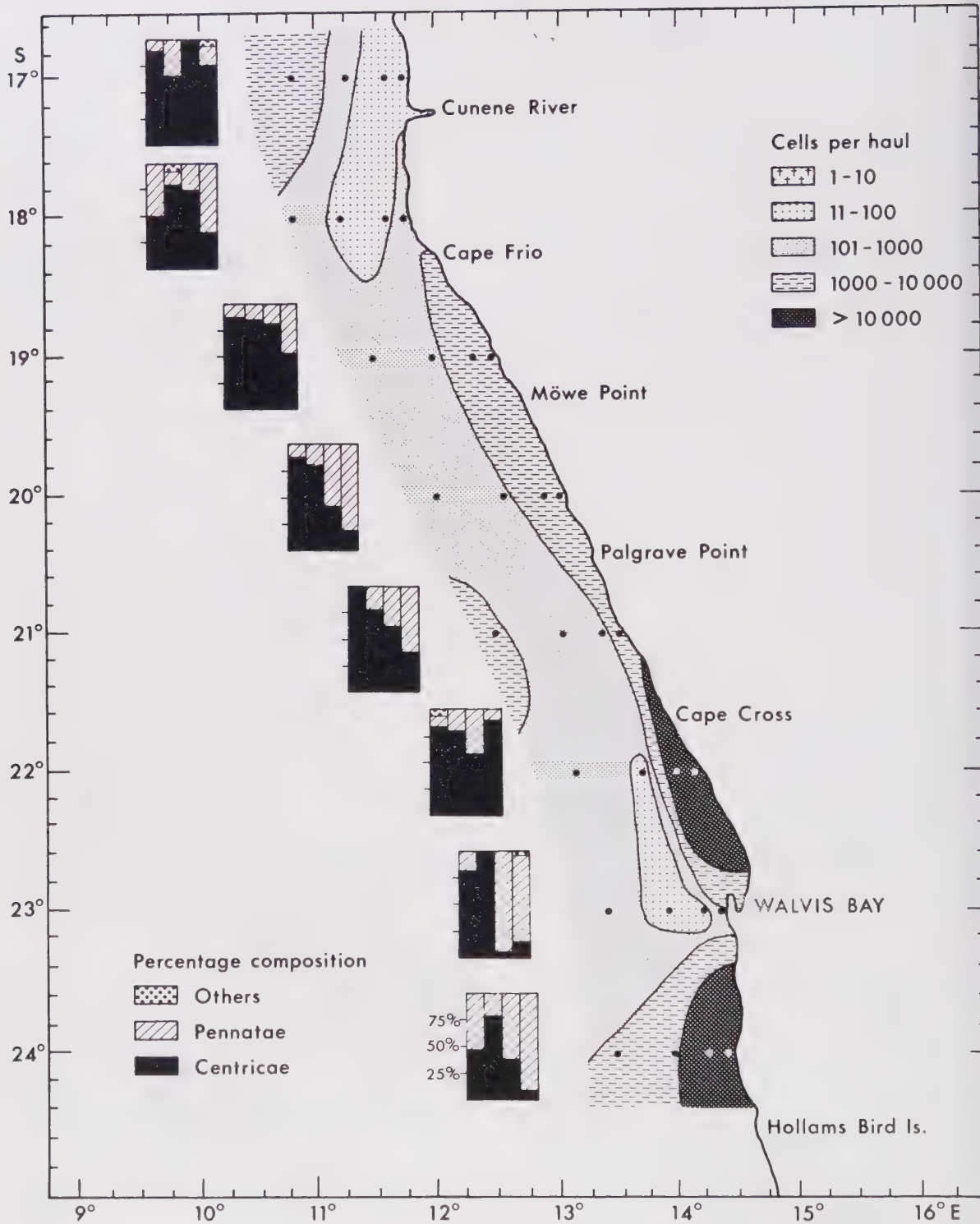

Fig. 6: Distribution and abundance of phytoplankton — July 1971 (Permission: I. Kruger)

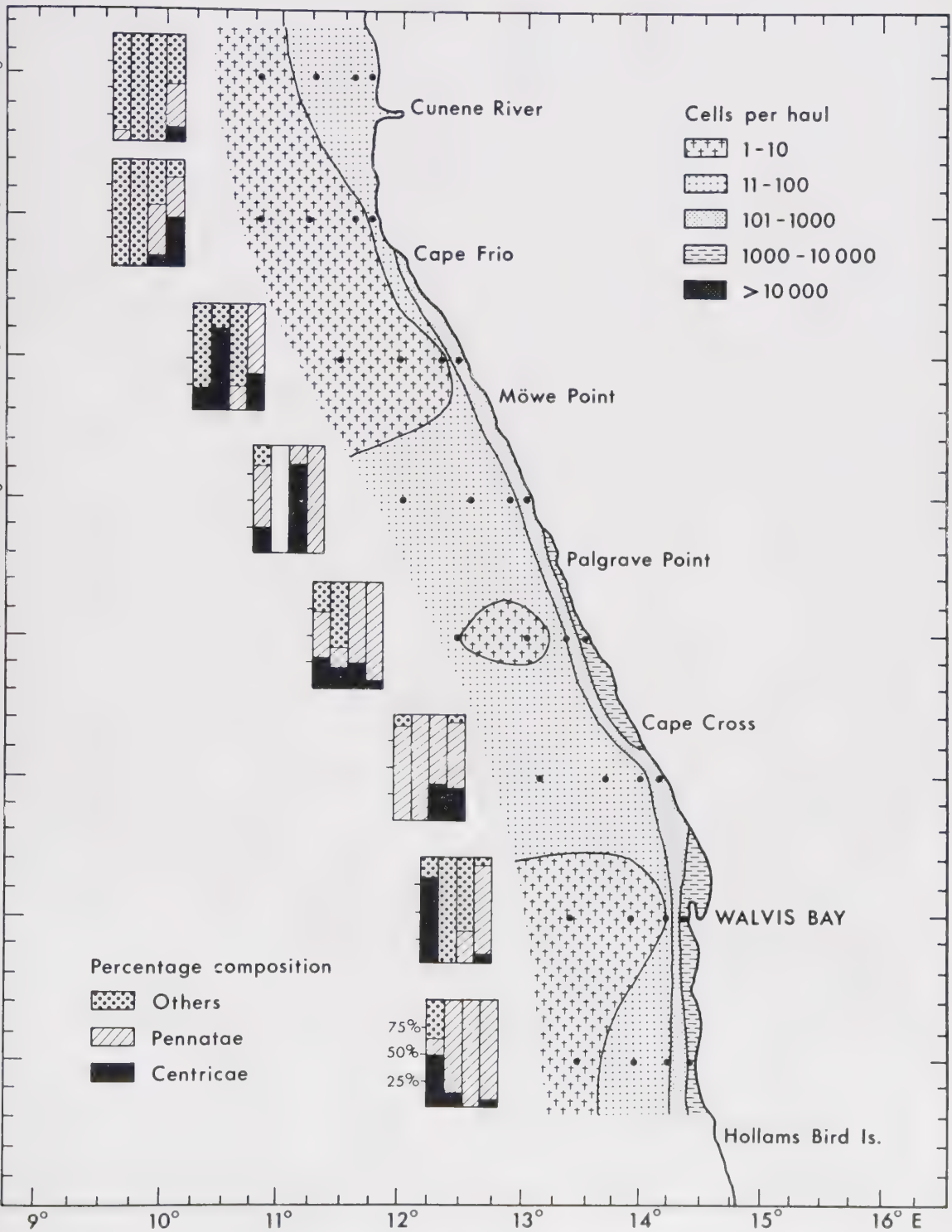

Fig. 7: Distribution and abundance of phytoplankton — January 1972 (Permission: I. Kruger)

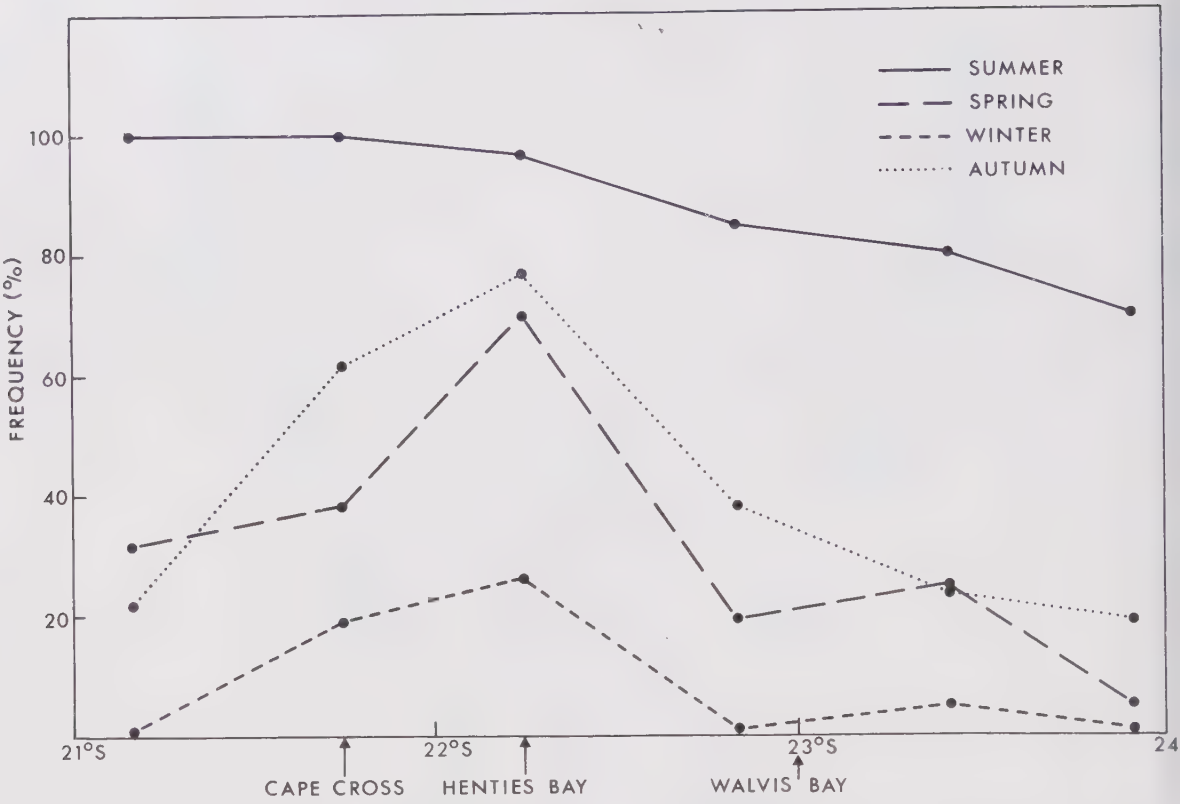

Fig. 8: Frequency-of-occurrence of thermoclines (data from Du Plessis 1967)

8, Du Plessis' data have been replotted to show the percentage frequency of thermocline occurrence in the long-shore direction. A region of high thermocline occurrence clearly exists between Cape Cross and Walvis Bay during autumn, winter and spring.

(ii) Dense concentrations of phytoplankton often occur between Cape Cross and Walvis Bay (Fig. 6), being the effect of water stability on plankton productivity (Barber *et al.* 1971). Du Plessis (1967) noted that the strong thermocline frequently encountered in this area could act as " . . . a thermal basin in which phytoplankton can develop under optimum conditions with the result that an uncommonly big bloom can occur" (Du Plessis *op. cit.*, p. 16), and he showed a roughly semicircular pool of high average phytoplankton density centred at about 22°20'S (Fig. 9).

(iii) Satellite photography has shown a plume of what appears to be fish factory effluent spreading northwards from Walvis Bay past Henties Bay (Cram 1979). Pieterse and Van der Post (1967) quoted an estimated annual pollution load of 13 000 short tons (dry basis) being placed in the sea, and noted the possible connection with phytoplankton blooms. De composition of the waste material would decrease the dissolved oxygen concentration at the same time as raising the phosphate nitrate and ammonia levels (A. Moldan, Sea Fisheries Institute, personal communication). Pieterse and Van der Post (*op. cit.*) found a close agreement between wind and current direction in Walvis Bay. During the fishing season (i.e. "winter" period) when the factories are in operation, the wind direction is predominantly from the south and the effluent can be expected to be transported northwards as shown on the satellite imagery. Whether the pollution would have an effect on the environment at any significant distance from Walvis Bay is not known. Extensive pollution should

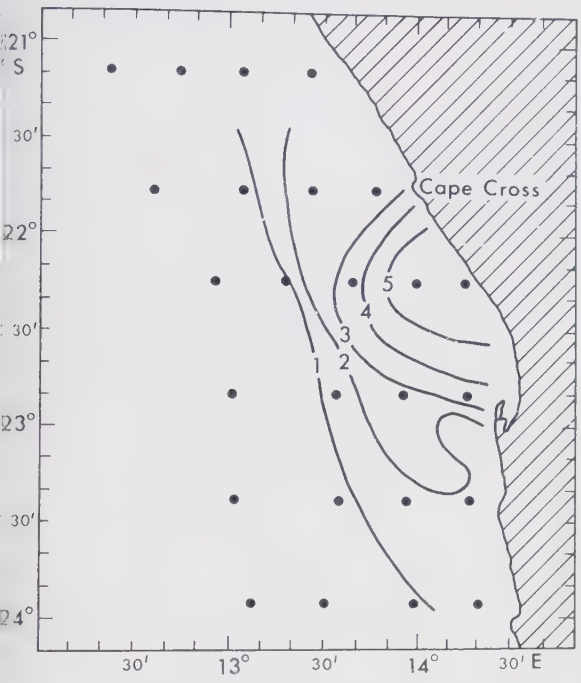

Fig. 9: Average monthly phytoplankton distribution in millions of cells (after Du Plessis 1967)

result in a positive horizontal oxygen gradient in the surface water to the north of Walvis Bay, but examination of the 1964—1965 oxygen data — routine stations III/1, IV/1, V/1 (Stander 1963) — showed positive and negative gradients occurring with more or less the same frequency. It is therefore inferred that pollution was not the primary cause of low oxygen values in that area, but more careful investigation is necessary to establish this inference conclusively. In the meantime, pollution must be borne in mind as a factor possibly contributing to and sustaining high phytoplankton production and low oxygen levels in the near-shore region between Cape Cross and Walvis Bay.

To summarize, a balance between upwelling nd thermocline formation during "winter", coupled ossibly with some degree of eutrophication from actory effluent, creates ideal conditions for hytoplankton growth between Cape Cross and Valvis Bay. The existence of a pool of high hytoplankton density (associated with low oxygen) ot only explains the low frequency of fish occurrence in that area, but also the previously noted tendency for the frequency maximum to shift southwards and northwards with distance off shore. This tendency is in agreement with the concept of fish shoals feeding in a zone along the perimeter of a coastal patch of high phytoplankton density. Schülein (1974) plotted pilchard catch positions for the 1973 fishing season: the highest density of catches occurred near shore in the vicinity of Walvis Bay and in the region Ambrose Bay — Palgrave Point. Fewer catches were made between Walvis Bay and Ambrose Bay, but the positions describe a clearly discernible off-shore curvature with hardly any catches close inshore.

During "summer", fish occurred with fairly even frequency all along the coast. This distribution is probably related to environmental conditions suggested by the summer (i.e. December — February) thermocline distribution curve (Fig. 8) of Du Plessis (1976). The frequency of thermocline distribution suggests uniform phytoplankton concentration along the coast with no exceptionally high density to be expected north of Walvis Bay. The map for January 1972 (Fig. 7) actually indicates a somewhat lower concentration in that area. The poorly defined minimum in the fish distribution curves (Fig. 3b) is, therefore, probably no more than a remnant from conditions during late spring.

Considering again the fish distribution in Figure 1 ("winter"), a line drawn through the axis of the highest frequency of fish occurrence describes a slightly convex curve between Palgrave Point and Conception Bay which presumably demarcates the zone where conditions were, on average, most favourable for pelagic fish. If the assumption is made that the fish distribution was solely, or at least predominantly, controlled by plankton density, then conditions should have been equally favourable for fish to occur with equal frequency everywhere along this zone. Clearly this is not the case. The frequency decreases from north to south and also from south to north reaching a minimum to the north of Walvis Bay, giving the impression that the fish started to move along a curved intermediate zone but encountered unfavourable conditions near the off-shore extent of the curve. Because Figures 6 and 9 suggest a smooth shape for the patch of dense plankton between Walvis Bay and Cape Cross, this minimum is not easily explained in terms of the intermediate-zone concept. When, however, the fish distribution is seen in conjunction with the superimposed contours of average surface temperature (Fig. 1) the frequency-of-fish-shoal-occurrence seems to be related to water temperature.

In the northern parts, isolines of fish occurrence tend to follow the isotherms, fish occurring with a relatively low frequency in water warmer than 15°C. Most prominent, however, is the shoreward intrusion of the 15°C isotherm between Walvis Bay and Cape Cross, coinciding with the region of minimum fish occurrence. De Vos and Visser (1972) compared commercial catch position frequencies and aerial fish-spotter data for 1971 with hydrological parameters. They stated that no pelagic fish were found in water where the surface temperature was more than 15,5°C and suggested that temperature was the factor controlling the extent of fish shoal distribution in the off-shore regions. As these findings agree with the general situation portrayed by Figure 1, it must be concluded that the existence of a semi-permanent coastward intrusion of warm water was either directly responsible for, or was at least indicative of unfavourable conditions, causing the infrequent occurrence of pelagic fish further off shore between Walvis Bay and Cape Cross during the "winter" period.

Figure 2 provides no evidence to suggest that temperature plays a role in establishing the "summer" fish distribution. The configuration of isolines is similar to that in the "winter" period, but temperatures are 1—1,5°C higher, and there are but weak indications of an intrusion to the north of Walvis Bay. Unfortunately, temperature data were not available for the near-shore region (less than 20 miles off shore), so the position of the 15°C isotherm is largely unknown.

As discussed earlier, fish shoals tended to be found closer to the coast during "summer", apparently as a result of an inshore shift of the intermediate zone. At this stage, however, it is necessary to consider the possibility of a thermal influence. Even though the average temperatures are not known for the inshore region, the values in Figure 2 indicate a decrease in temperature towards the coast. The effect of phytoplankton density can therefore, in this case, not be separated from a possible thermal influence. On the other hand, shoals frequently occurred in water warmer than 15°C — certainly a large section of the 31—50 per cent frequency-of-occurrence contour overlaps into water warmer than 17°C, a fact which opposes the idea of a direct thermal influence. In view of the somewhat contradictory nature of the available evidence, no definite conclusion can be drawn regarding the effect of temperature on pelagic fish distribution, but it would appear that a thermal influence could be exerted after the requirements for satisfactory feeding conditions have been satisfied.

SUMMARY AND CONCLUSIONS

Aerial fish-spotting data have been used to delineate the general distribution of pelagic fish along the South West African coast in terms of the frequency with which shoals were detected. A difference between "summer" and "winter" distributions was found. During "summer", the fish occurred fairly evenly along the coast whereas, in "winter", shoals were mainly detected in the area of Cape Cross and, less frequently, south of Walvis Bay. Although the maximum frequency-of-occurrence was, on average, situated further off shore during "winter", shoals mostly occurred over a smaller geographical area during this period. Other factors disregarded, the distribution of fish occurrence during "winter" appears to be most favourable to operations aimed at fish stock estimations by aerial and acoustic surveys.

During "winter", shoals were located with low frequency in the near-shore region between Walvis Bay and Cape Cross. The highest frequencies were found 10—20 nautical miles from the coast, between Palgrave Point and Ambrose Bay, and in the south between Sandwich Harbour and Conception Bay. Between these two areas, fish seemed to occur most commonly on the perimeter of a slightly convex curve joining these two positions.

An attempt has been made to explain the observed distributions in terms of environmental conditions. The arguments employed were of generalized and occasionally speculative nature but, nevertheless, support previous findings that phytoplankton density and water temperature play important roles in the determination of pelagic fish shoal distributions. In this respect, conditions between Walvis Bay and Cape Cross seem to be of particular interest. During "winter" especially, fish shoals occurred with low frequency in the area, apparently as a result of unfavourably high phytoplankton concentrations close to the coast coupled with a shoreward extension of warm off-shore water. In combination, the high temperature and dense phytoplankton appear to act as a barrier to shoal movement, thereby affecting to a large degree the distribution of pelagic fish along the entire coast.

Finally, it must be pointed out that the results obtained in this study are of somewhat uncertain value when applied to conditions at present pertaining to the pelagic fishery of South West Africa. As indicated earlier in the report, the largest portion of the fish-spotting data relates to

pilchard shoals with relatively small contributions of anchovy and horse mackerel. In recent years, however, the situation has changed, the pilchard population having declined sharply and having been superseded by anchovy as the numerically more important species. Fortunately, an analysis of commercial catch positions for the period 1971—1973 (F. H. Schülein, Sea Fisheries Institute, unpublished manuscript) showed almost identical catch distributions for all three species, which suggests that, whereas the aerial observations contain a bias towards pilchard, the results would, at least as far as the "winter" period is concerned, also apply reasonably well to anchovy and horse mackerel.

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1980

OBSERVATIONS ON THE MORTALITY OF JUVENILE CAPE CORMORANTS *PHALACROCORAX CAPENSIS* DURING 1975 AND 1979

R. J. M. CRAWFORD, P. A. SHELTON, A. L. BATCHELOR and C. F. CLINNING***

Rainfall at Dyer Island and suppurative conjunctivitis, heavy seas and nest desertion at Ichaboe Island during 1979, as well as nest desertion at Swakopmund during 1975, caused mortality of Cape cormorant *Phalacrocorax capensis* juveniles. Nest desertion was most important and is attributed to insufficient food. Off southern Africa, marked decreases in the numbers of Cape cormorants may be a useful indicator of similar trends in pelagic fish abundance.

Reën op Dyer-eiland en ettervormende konjunktivitis, stormagtige see en nesverlating op Ichaboe-eiland gedurende 1979, asook nesverlating te Swakopmund gedurende 1975, het vrekte onder jong trekduikers *Phalacrocorax capensis* veroorsaak. Nesverlating was die hoofoorsaak en word toegeskryf aan 'n voedseltekort. Langs die kus van suider-Afrika kan skerp dalings in die getal trekduikers dien as betroubare aanduiding van 'n dergelike tendens in die talrykheid van pelagiese vis.

A number of the pelagic fish stocks occurring in the Benguella Current region off southern Africa have exhibited large fluctuations in recruitment (Geldenhuys 1973, Centurier-Harris 1977, Newman and Crawford in press), which are thought to be influenced by environmental factors (Siegfried and Crawford 1978, Shelton and Hutchings 1979) and which complicate management (Crawford 1979). Conventional assessments based on catch and effort information and also direct surveys, involving acoustic and aerial techniques and quantitative assessments of eggs and larvae, have failed to provide adequate warning of decreases in stock size. In the past this has led to overfishing and severely reduced fish populations (Butterworth in press).

Resource managers will require up-to-date estimates of fish abundance if, in future years, they are to take account of the dynamic nature of the fisheries in establishing quota levels. Seabird populations along the coast of South West Africa are closely linked to the local availability of food and are potentially useful as indicators of the state of pelagic fish resources (Crawford and Shelton 1978). However, some understanding of the possible rate of increase or decrease of seabird populations is necessary before this method can be used with greater confidence.

There is little documentation on mortality of the Cape cormorant *Phalacrocorax capensis*, which in 1978 was the most numerous of southern African guano-producing seabirds (Crawford and Shelton in press). Rand (1960, p.6) noted that the birds of this species " . . . may summarily desert their nests at any stage of breeding. The resulting widespread destruction of eggs and partly fledged chicks is perhaps one reason why the population is so unstable." Berry (1976a) observed predation by black-backed jackal *Canis mesomelas*, brown hyaena *Hyaena brunnea*, cheetah *Acinonyx jubatus*, white pelican *Pelecanus onocrotalus*, white-breasted cormorant *Phalacrocorax carbo* and southern black-backed gull *Larus dominicanus*, but concluded that the total effect of all predators on the population of Cape cormorants was negligible. In 1974, fish oil pollution was responsible for the death of at least 4 500 Cape cormorants in the Walvis Bay vicinity (Berry 1976b) and caused heavy mortality of seabirds at Lambert's Bay (Anon. 1974). All localities mentioned are shown in Figure 1. Mineral oil spills at sea are also known to affect cormorants (Rowan 1969, Westphal and Rowan 1971).

To supplement these findings on mortality of Cape cormorants, observations made during 1975 and 1979 are discussed.

RAINFALL AT DYER ISLAND

Measurements of rain at Dyer Island are available for the first three months of 1979 (Fig. 2). On two successive days, 27 and 28 February, rainfall amounted to 30 mm or more and was directly responsible for the death of approximately 800 Cape-cormorant chicks that were in the late downy stage. The situation was aggravated by the concave

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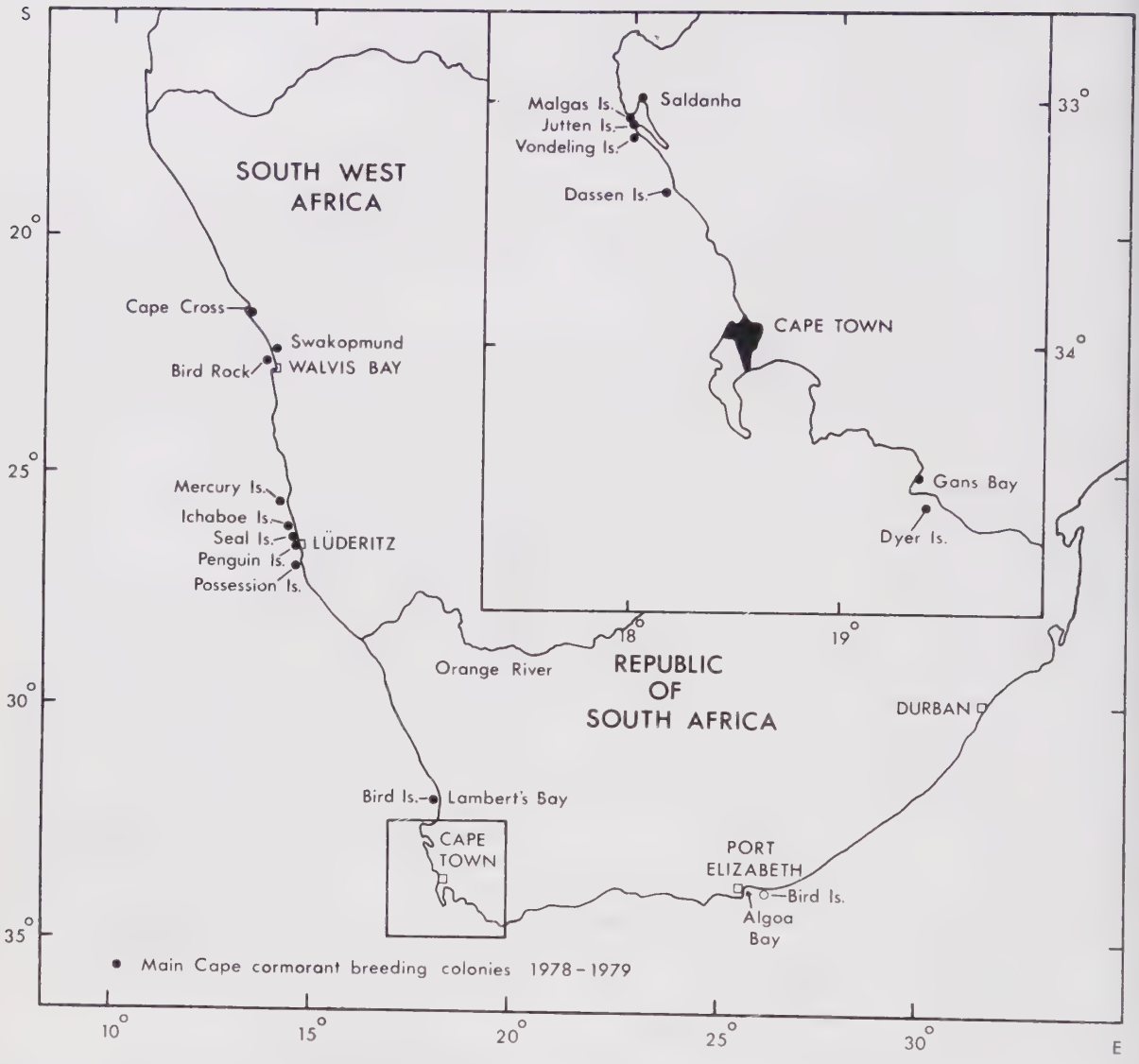

Fig. 1: The west coast of southern Africa, showing localities of the main Cape cormorant breeding colonies in 1978–1979

topography of the island, which caused water to collect in large pools. No deaths were observed when rainfall was less heavy. As at Bird Island, Algoa Bay, where pools of rainwater probably caused mortality of Cape gannet *Sula capensis* eggs and chicks in 1976 (Randall and Ross 1979), the concave topography is likely to have resulted from excessive guano scraping.

SUPPURATIVE CONJUNCTIVITIS AT ICHABOE ISLAND

During the period early January to early March 1979, suppurative conjunctivitis caused the death of approximately 5 000 Cape cormorant and 100 bank cormorant *Phalacrocorax neglectus* chicks

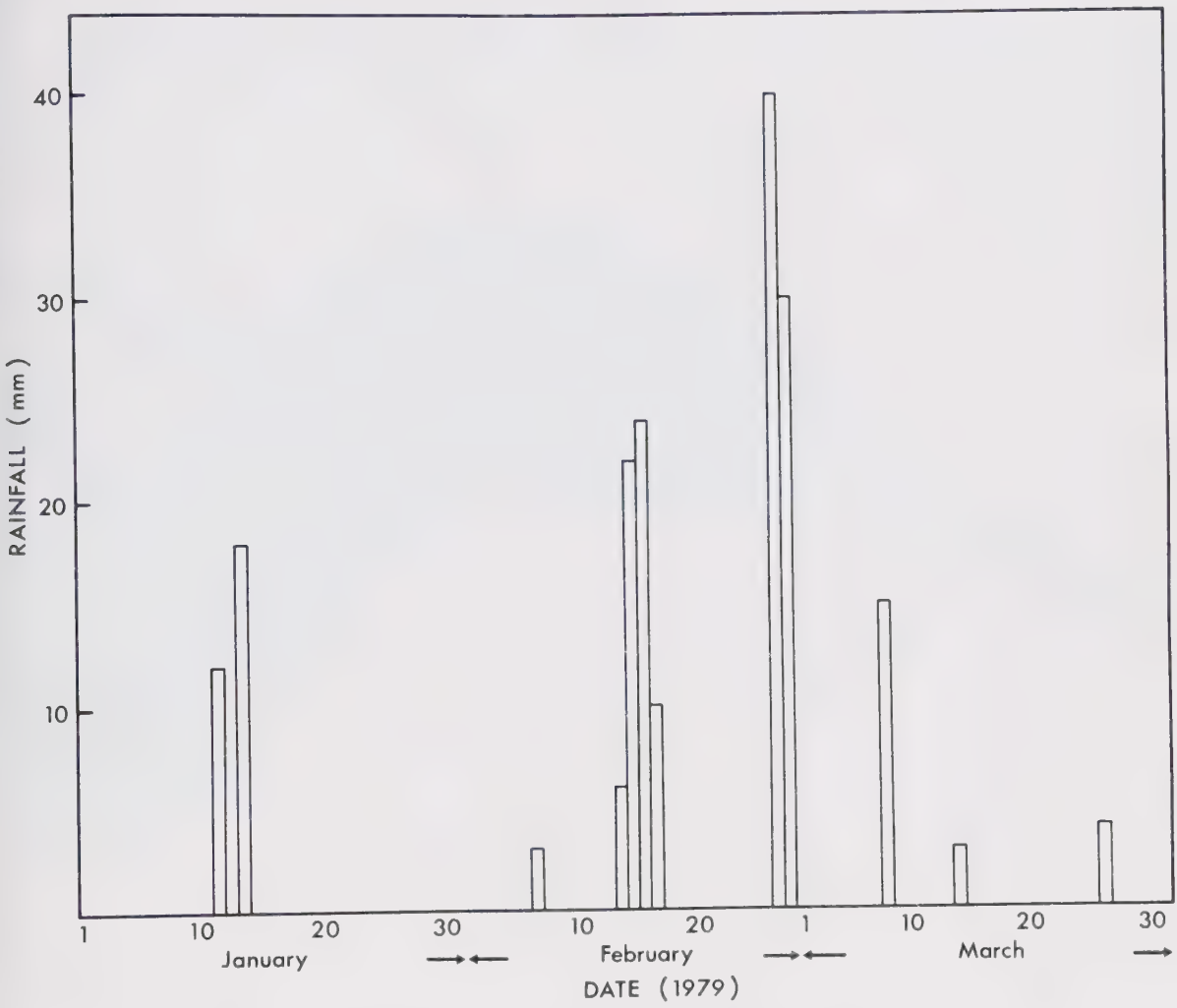

Fig. 2: Rainfall at Dyer Island, January — March 1979

at Ichaboe Island. A purulent exudate was found to cover the cornea. It also spread over the eyelids, forming crusts (Fig. 3). Birds affected ranged from six-week-old chicks to those that were fully fledged. Four Cape cormorants were taken for analysis to Groote Schuur Hospital's Department of Bacteriology and Virology, and species of bacteria belonging to the genera *Staphylococcus* and *Haemophilus* were isolated. These organisms could have been responsible for the contagious suppurative infection of the eyes.

HEAVY SEAS AT ICHABOE ISLAND

The main seabird breeding area at Ichaboe Island is surrounded by a sea wall (Rand 1963), but this was insufficient to keep out heavy seas (driven predominantly by south-westerly winds) from 9—16 and 26—27 February 1979. A considerable portion of the island was then flooded (Fig. 4) and at least 200 Cape-cormorant and 40 bank-cormorant nests were destroyed.

Fig. 3: Cape cormorant suffering from suppurative conjunctivitis at Ichaboe Island, February 1979

NEST DESERTION AT ICHABOE ISLAND

On 31 March and 1 April 1979, all Cape-cormorant nests at Ichaboe Island were deserted by the adults, and intensive predation on eggs and chicks by southern black-backed gulls and by pied crows *Corvus albus* followed. A subsequent count showed the total number of deserted nests to be in excess of 15 000, and more than 14 000 dead Cape-cormorant chicks, mostly at the medium to large downy stage, were observed. Feeding success during the last two weeks of March was low, chicks soliciting their parents frequently but seldom receiving food, and lack of sufficient prey was probably the main reason for desertion.

The Cape gannet is another predator of pelagic fish (Rand 1959), and the colony of this species at Ichaboe Island was also adversely affected by insufficient food in late March 1979. Although no desertion occurred, approximately 4 000 chicks starved to death.

NEST DESERTION AT SWAKOPMUND

During April and May 1975, considerable numbers of Cape cormorant pulli, still unable to fly, were

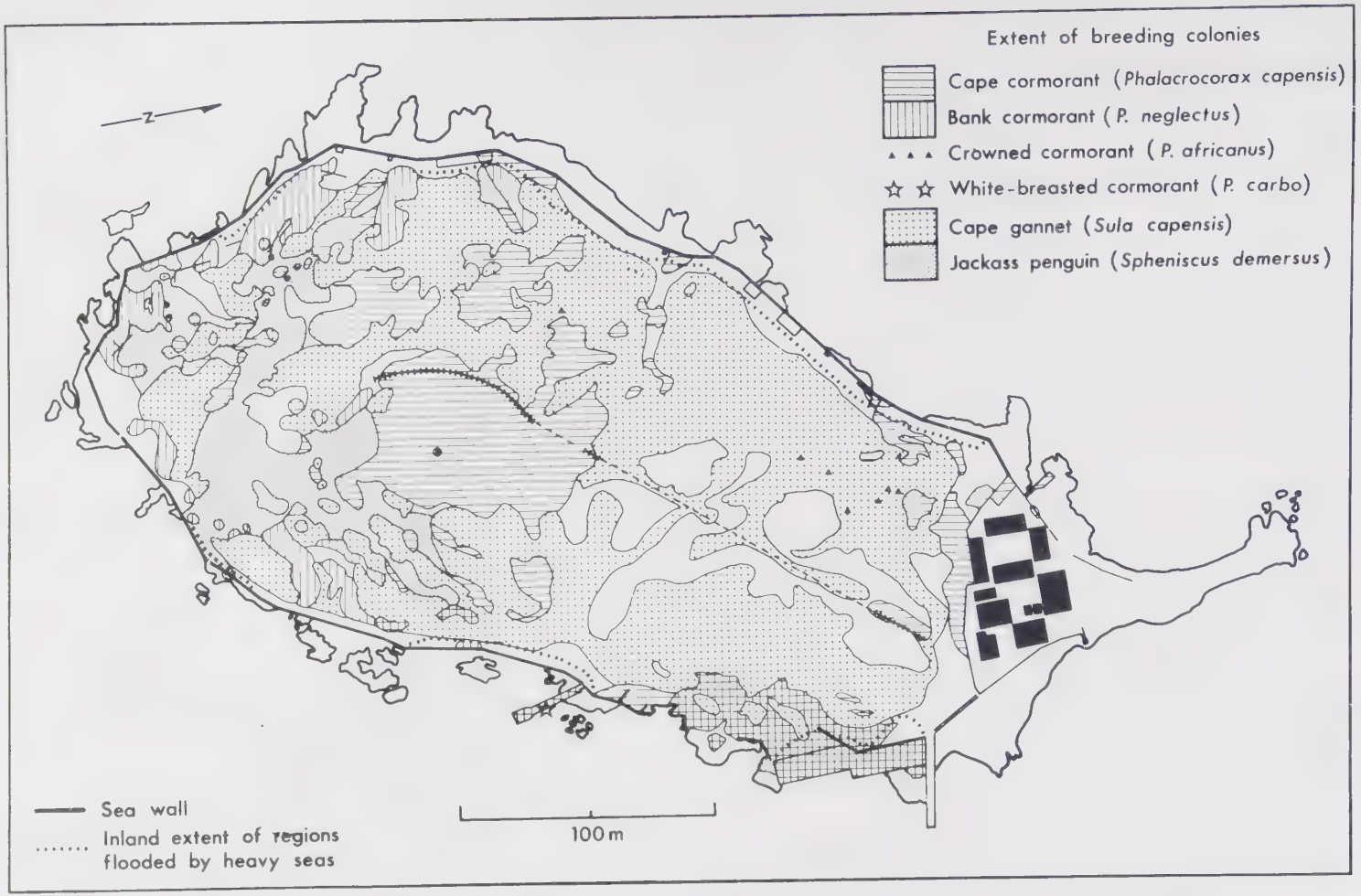

Fig. 4: Ichaboe Island (26°17,5'S; 14°26,2'E), showing extent of breeding colonies on 28 November 1978 and region flooded by heavy seas during February 1979 (crowned comorants also breed underneath the platforms at the north-east of the island)

observed along the coastal road between Swakopmund and Cape Cross in South West Africa (Fig. 1). Some had wandered up to 5 km from the nearest breeding locality, the Swakopmund guano platforms. These platforms were visited on 23 and 24 April when about 5 000 juvenile birds were present, the vast majority of which were in a weakened condition and not being attended by adults. Numerous dead chicks were also seen. Discussions with the platforms' owners revealed that, after a prolonged breeding season, adults had deserted their broods and had moved north to platforms in the Cape Cross lagoon.

Two live but emaciated Cape-cormorant chicks were sent for examination to the Regional Veterinary Laboratory, Windhoek. Their intestines revealed high counts of the bacterium *Clostridium perfringens,* suggesting that resistance of the juvenile birds to infection was reduced following hunger stress. In 1957—1958, pilchard *Sardinops ocellata* constituted 89 per cent by mass of the diet of Cape cormorants in the Walvis Bay vicinity (Matthews 1961). In 1975, the biomass of the South West African pilchard stock was substantially lower than at any stage since 1957, the first year for which estimates are available (Table I), and the severe decline of this population may have been responsible for the high mortality of young Cape cormorants.

Table I: Biomass estimates for the South West African pilchard population, 1957—1977

Year(s)	Biomass (thousands of metric tons)	Year	Biomass (thousands of metric tons)
1957—1960	5 670*	1972	2 562**
1963—1966	6 800*	1973	2 436**
1967	4 025**	1974	2 045**
1968	3 745**	1975	1 457**
1969	2 844**	1976	960**
1970	2 196**	1977	601**
1971	2 318**		

* Estimates from tagging (Newman 1970)
** Estimates from virtual population analysis assuming an instantaneous natural mortality rate of 0,3 (Schülein *et al.* 1978)

DISCUSSION

Observed mortality of Cape-cormorant juveniles in 1975 and 1979 indicates that annual recruitment can be severely reduced by poor availability of food. Large numbers of chicks died at both Ichaboe Island and Swakopmund after desertion by adults. Suppurative conjunctivitis and heavy seas at Ichaboe Island also adversely influenced population numbers, but their contribution to mortality was less significant than that of nest desertion. At Dyer Island, the 800 chicks that died as a result of heavy rainfall would have amounted to only a small proportion of the juvenile birds present, because 35 580 pairs of Cape cormorant bred at the island during the summer of 1978/79 (Crawford and Shelton in press).

Berry (1976a) concluded that starvation stress during the post-fledging period is the biggest single cause of mortality in free-flying Cape cormorants. Food appears to be the most important factor influencing survival of this species and, consequently, a large decline in the numbers of Cape cormorants is likely to be indicative of a similar trend in pelagic fish stocks.

ACKNOWLEDGEMENTS

The authors wish to thank Mr B. H. Smith for conducting the field observations at Ichaboe Island, Drs G. A. Keen and M. Scott of the Department of Bacteriology and Virology at Groote Schuur Hospital for analysis of the four Cape cormorants suffering from suppurative conjunctivitis and the Regional Veterinary Laboratory, Windhoek, for examining the two birds infected with *Clostridium perfringens.* We are grateful to Dr R. W. Rand of the Department of Nature and Environmental Conservation of the Cape Provincial Administration and Mr R. K. Brooke of the Percy Fitzpatrick Institute of African Ornithology for commenting on the manuscript.

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n. Bull. S.Afr. 13:77–82
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EXTENSION TO THE GEOGRAPHICAL DISTRIBUTION OF PELAGIC GOBY *SUFFLOGOBIUS BIBARBATUS* OFF SOUTH WEST AFRICA AND SOME MENSURAL AND ENERGETIC INFORMATION

R. A. CRUICKSHANK, J. COOPER AND I. HAMPTON*

The geographical distribution of the pelagic goby *Sufflogobius bibarbatus* in South West African waters was deduced from extensive hydroacoustic surveys conducted in 1978 and 1979 and, for adults, is wider than previously recorded. The distribution is discontinuous with a consistent gap between roughly 26°30′S and 28°S. The gap is evident in the results of hydroacoustic surveys and analyses of bank-cormorant *Phalacrocorax neglectus* regurgitations and coincides with the presence of large, surface-visible *Ecklonia maxima* kelp beds close to the coast. The length-mass relationship, water content and energy values are given for a species of fish whose commercial importance may increase.

Die geografiese verspreiding van die oseaan-dikkop *Sufflogobius bibarbatus* langs die kus van Suidwes-Afrika is afgelei van uitgebreide hidro-akoestiese opnames wat gedurende 1978 en 1979 gedoen is en, in die geval van die volwassenes, is gevind dat dit meer uitgebrei is as wat tevore aangeteken was. Die verspreiding is diskontinu, met 'n konstante gaping tussen ongeveer 26°30′S en 28°S. Hierdie gaping word aangetref in hidro-akoestiese bevindings en dié van 'n analise van uitbraaksels van die bankduiker *Phalacrocorax neglectus* en dit val saam met die voorkoms van groot beddings van die kelp *Ecklonia maxima* aan die oppervlak naby die kus sigbaar. Die lengte-massaverhouding, water-inhoud en energiewaardes word aangegee vir 'n visspesie waarvan die kommersiële belang moontlik sal toeneem.

The pelagic or bearded goby *Sufflogobius barbatus* (Von Bonde) was first recorded in South est African waters by Barber and Haedrich (1969). Toole (1976) found it to be abundant and widely stributed between Hollams Bird Island (24°38′S) d Möwe Point (19°23′S) and up to 85 km off ore. The southern limit of the species in South est African waters was not defined by O'Toole *p. cit.*), because his survey did not extend south Hollams Bird Island. The recorded range of the ecies in South Africa is from St Helena Bay on west coast to St Sebastian Bay on the south-t coast (Smith 1965).

This report provides evidence of further exten-ns to the known distribution off South West rica and the west coast of South Africa. The eviously recorded distribution of the pelagic by in southern African waters is reflected in gure 1 together with the extended distribution scribed here.

To date, no mensural or energy data have been blished for the pelagic goby. Because of the use such information in fisheries research and in timating the food and energy intake of predators, has been incorporated in this report.

MATERIALS AND METHODS

Between October 1978 and June 1979 (May excepted) the Sea Fisheries Institute undertook a monthly series of joint hydroacoustic and egg and larva surveys (SWAPELS) in the area from south of the Cunene River (17°40′S) to Lüderitz (26°40′S). Also, during the first five months, a less intensive survey was mounted in the area between Lüderitz and the Olifants River (31°40′S). The R. S. *Benguela* was used for all surveys and, for the duration of four of the cruises, a commercial purse seiner was contracted to sample selected sound-scattering targets.

The main SWAPELS grid is shown in Figure 2. The sampling lines were 20 nautical miles apart and ran from 2 to 65 miles off shore with stations at 2, 5, 10, 15, 25, 35, 45, 55 and 65 miles. The less intensively surveyed area south of Lüderitz was only covered to 25 miles off shore. At each station, oblique bongo-net tows were made from 50 m to the surface where the depth was sufficient, or from within a few metres of the bottom in shallow coastal waters. In all surveys, paired bongo nets of 57-cm diameter mouth opening were used, as in previous SWAPEL surveys (King and Robertson 1973). The left-side net had a mesh of 0,94 mm and the right 0,30 mm. At two knots, the net was in the water for an average of 10 minutes per tow.

A high-frequency (120 kHz) echo-sounder with calibrated range compensation and a 24-kHz sonar were used throughout the surveys for the purpose of detecting fish shoals and sound-scattering layers. The sounder detected targets directly below the

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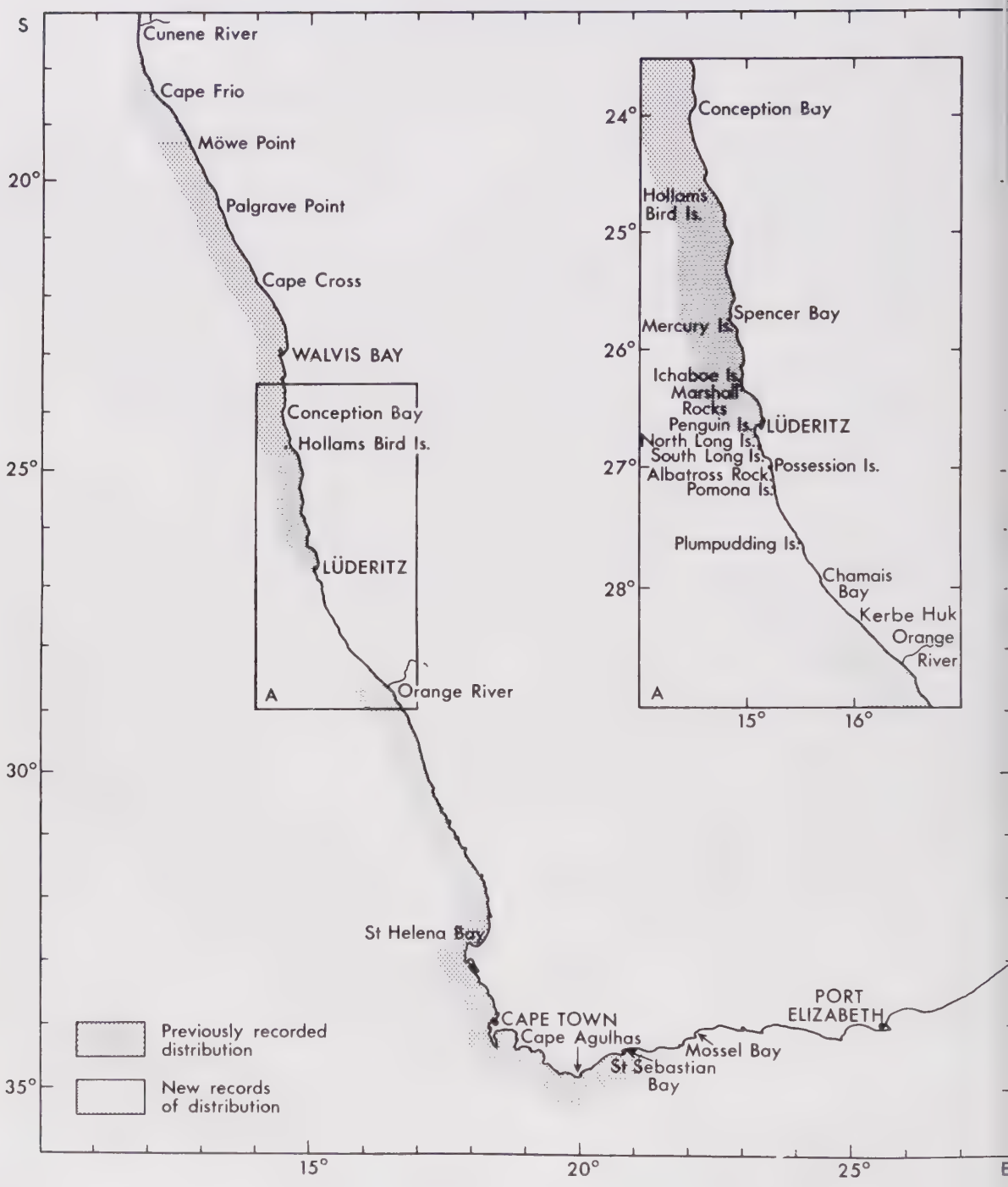
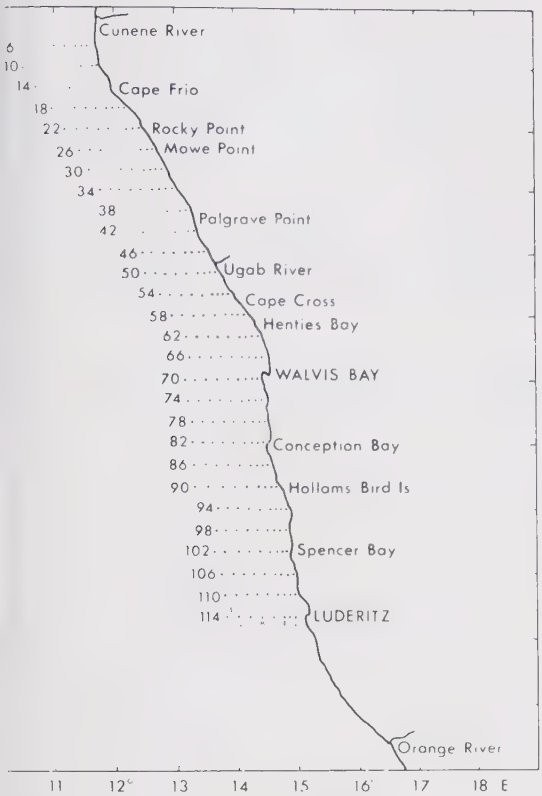


Fig. 1 Distribution of the pelagic goby *Sufflogobius bibarbatus* in southern African waters



2: The main SWAPELS grid off South West Africa

) while the sonar surveyed a 500 m wide swath ellel to the ship's track. Sound-scattering layers fish shoals were identified by means of directed se-seine catches and examination of the appro- te bongo-net samples. Some bongo tows were de specifically to identify acoustic targets.

ome further information on the southern ribution of the goby was obtained on a demersal wl sampling cruise conducted from R.S. *icana II* in July 1979. Sampling on this cruise ended from south of the Olifants River to rbe Huk, (A. I. L. Payne, Sea Fisheries Institute, sonal communication). Trawls sampled a)-m wide swath and a height of 5 m off the tom and lasted one hour. The codend of the landic otter trawl was lined with 27,5 mm mesh chard netting (Payne 1979) and thus retained tually all fish.

As part of a study of the diet of the bank rmorant *Phalacrocorax neglectus* (Aves: Phala- coracidae), the island colonies off South West Africa were visited during November and December 1978 in order to obtain samples of their food. Further collections were made on Ichaboe Island during May — July 1979.

The islands visited are shown in the inset to Figure 1. On some of these islands, bank cormorants were captured on their nests and induced to regurgitate food. Natural regurgitation pellets were collected from nesting colonies on all islands. Regurgitated food samples were sorted and the component prey items were identified to species level. Pellets were soaked and then broken up in order to record the presence or absence of pelagic-goby otoliths.

A total of 200 undigested pelagic gobies was taken from food samples collected on Ichaboe Island and each one weighed to the nearest 0,1 g using a Pesola spring balance. The caudal length (L_c) was measured to the nearest millimetre and 27 individuals, representing the length range of all fish collected were deep-frozen in individual plastic bags. They were defrosted in the laboratory, dried to constant weight (mass) in a forced-draught oven at 50°C and seven of them, representing each 10-mm length class of the collected size range, analysed for energy value in a Gallenkamp ballistic bomb calorimeter.

RESULTS AND DISCUSSION

Distribution determined from ichthyoplankton and acoustic surveys

During the SWAPELS cruises, the pelagic goby was often found in continuous sound-scattering layers many miles long (Fig. 3). This finding agrees with that of d'Arcangues (1977), who reported similar sound-scattering layers in this area, some of which she attributed to gobies. Pelagic gobies represented 59,2 per cent (range 20,5 — 88,5 per cent) of all incidental fish species collected in bongo-net tows from October 1978 to June 1979 (Table I). However, they were not found north of Palgrave Point (20°20′S) from October 1978 to January 1979. The species was always widespread south of Walvis Bay (23°S) except in February when it was confined to the south of 24° 20′S. From February to April 1979, gobies were found well beyond Cape Frio as far north as 17°40′S near the Cunene River, but north of Walvis Bay the distribution was patchy.

Such substantial extensions of the geographical

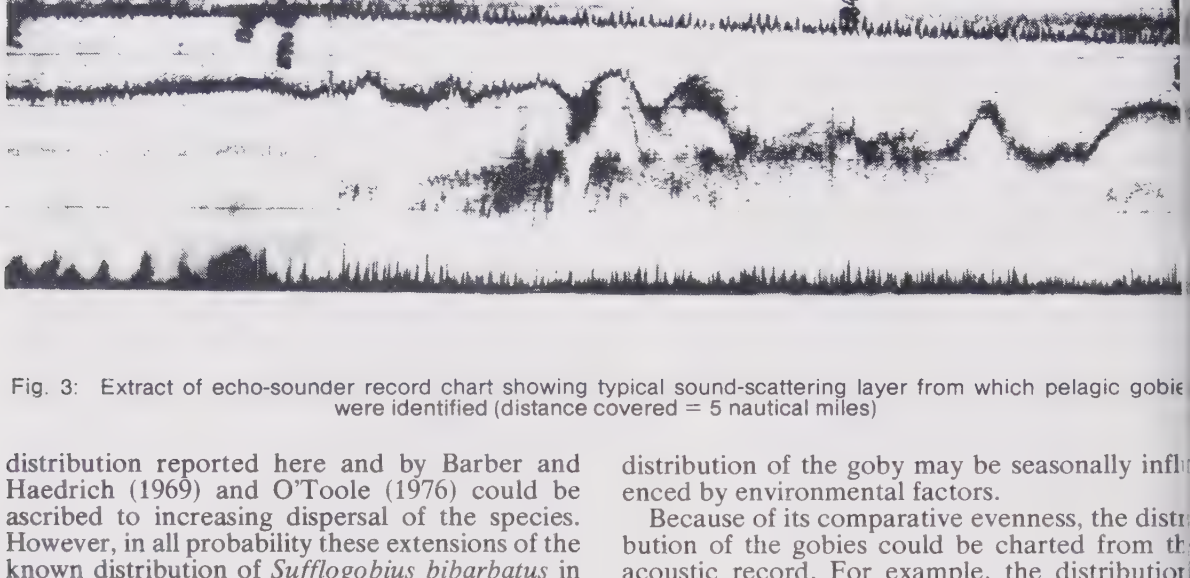


Fig. 3: Extract of echo-sounder record chart showing typical sound-scattering layer from which pelagic gobie were identified (distance covered = 5 nautical miles)

distribution reported here and by Barber and Haedrich (1969) and O'Toole (1976) could be ascribed to increasing dispersal of the species. However, in all probability these extensions of the known distribution of *Sufflogobius bibarbatus* in large part reflect the increased data intake from the more intensive research activity off the coast of South West Africa in recent years.

The South West African coast is an area of strong seasonal upwelling with resultant fluctuations in temperature and salinity gradients. O'Toole (1976) reports that gobies caught during the 1972 —1974 surveys were found at temperatures ranging from 14,5 to 17.5°C. Therefore, variations in the distribution of the goby may be seasonally infl enced by environmental factors.

Because of its comparative evenness, the distr bution of the gobies could be charted from th acoustic record. For example, the distributio plotted in this way for January — April 1979 a shown in Figure 4. Also, because of the distinctne and continuity of the layer (Fig.3), the isolate identification catches were considered to b sufficient to specify the composition of the laye over wide areas. Shoals of gobies were frequentl recorded acoustically from inshore to 35 nautica miles off shore. They were identified in 27,4 pe cent of all hauls within a seaward range of 3 miles between Walvis Bay and Lüderitz. Denses concentrations were found in this same stretch c water; 76,8 per cent of all positive hauls less tha 35 miles off shore between Walvis Bay and Lüderit contained gobies. This finding is consistent wit that of O'Toole (1976, 1978), that the highes densities of larval, juvenile and adult gobies occu between Walvis Bay and Hollams Bird Island Pelagic gobies were not recorded between Lüderit and Kerbe Huk.

Bongo-net and trawl samples containing pelagi gobies were collected between Kerbe Huk an the Orange River (Le Clus and Cruickshank 197 A. I. L. Payne, Sea Fisheries Institute, persona communication) and the species was also occa sionally found between the Orange River and S Helena Bay during the SWAPEL and trawlin surveys. Gobies in South African waters therefor extend beyond the northern limit on the wes coast (St Helena Bay) reported by Smith (1965).

Table I: Pelagic gobies caught in plankton nets during SWAPEL surveys, 1978/79

Month of survey	Total fish caught	Gobies caught		Number of stations at which caught
		Number	Per cent	
October 1978	439	361	82,2	35
November 1978	166	34	20,5	17
December 1978	546	405	74,2	42
January 1979	569	264	46,4	29
February 1979	303	200	66,0	26
March 1979	321	113	35,2	32
April 1979	171	103	60,2	25
June 1979	26	23	88,5	3
Mean	318	188	59,1	26

Fig. 4: Monthly distribution of pelagic goby produced from acoustic records, January — April 1979

stribution determined from predation by bank morants

Totals of 52 food samples collected on Mercury, haboe and Penguin Islands during November — ecember 1978 and of 22 samples collected on haboe Island during May — July 1979 consisted tirely of pelagic gobies. Regurgitation pellets llected on these three islands consisted almost tirely of goby otoliths and bones (other items ere present in less than 2 per cent of the samples). n the islands between North Long Island and umpudding Island (refer Fig. 1), gobies were not entified from stomach contents or from regurgi-tion pellets.

Therefore, the results from analysis of the omach contents of bank cormorants and those from survey observations show a well defined gap in the distribution of the pelagic goby in southern South West African waters. This gap is evident throughout the year and occurs between 26°30'S and 28°S. It has been observed that there are dense beds of surface-visible kelp *Ecklonia maxima* along the coast in this area, with the northern limit being Lüderitz (Day 1974). Dense patches of surface-visible *E.maxima* are rare between Kerbe Huk and the Orange River (C. G. Wilke, Sea Fisheries Institute, personal communication). There is no kelp visible at the surface around Mercury or Ichaboe Islands and little around Penguin Island, but the islands south of Lüderitz do support *E.maxima* beds off shore (J. C., personal observation). *E.maxima* does occur at Marshall Rocks near Ichaboe Island (Beyers 1979), but it is not

visible at the surface.

It is possible that gobies could be excluded from areas of abundant kelp, though this might not be so much a direct species interaction as the function of some common influence such as the substratum.

Mensural and energy data

The length-mass relationship for the pelagic goby is reflected in Figure 5. Water content and

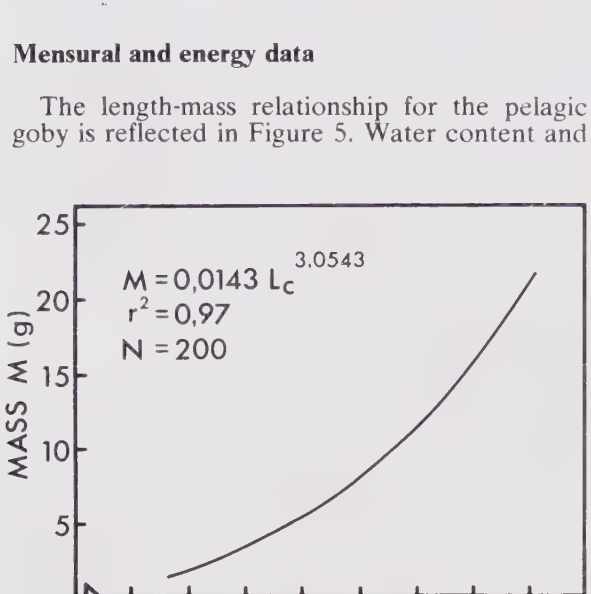


Fig. 5: Length-mass relationship of the pelagic goby *Sufflogobius bibarbatus*

energy values are presented in Table II. Neither value varied significantly with the size of fish studied over the length range 46—108 mm, regression analysis showing less than 20-per-cent correlation.

Because the pelagic goby may in future be commercially exploited on a large scale (Cram 1977, O'Toole 1978, Le Clus and Cruickshank 1979), such information may be useful in bas research.

Table II: Water content and energy values of the pelagic goby *Sufflogobius bibarbatus* from South West African waters

Value	Mean	Standard deviation	Range	Number analysed
Water content (%)	83,6	2,0	78,6-87,1	27
Energy (kJ/g dry mass)	22,5	2,0	19,8-25,3	7

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DISTRIBUTIONAL ECOLOGY OF THE LARVAE AND JUVENILES OF THE ANCHOVY *ENGRAULIS CAPENSIS* GILCHRIST IN RELATION TO THE HYDROLOGICAL ENVIRONMENT OFF SOUTH WEST AFRICA, 1978/79

A. BADENHORST and A. J. BOYD

The distribution of anchovy larvae in relation to the hydrological environment off South West Africa was studied from October 1978 to April 1979 and compared with the results of previous surveys. Differences in total coverage and in mesh sizes of nets between this survey and previous ones precluded comparative stock assessments. Larvae more than 7 mm long exhibited net avoidance during the day, leading to their undersampling. Larvae were found to be abundant in water of 16-24°C, but most of those caught in water above 21°C were small (less than 4 mm in length). The possibility of larval import into the survey area is discussed. Both occurrence and survival of larvae are influenced by differing hydrological conditions in different areas, and three regions of greater abundance separated by areas of lower occurrence or absence are identified. On two occasions, growth rates could be estimated by following a larval cohort in successive months, and length increments of 0,6 mm and 0,9 mm a day were calculated.

Van Oktober 1978 tot April 1979 is die verspreiding van ansjovislarwes met betrekking tot die hidrologiese omgewing langs die kus van Suidwes-Afrika bestudeer, en dit is met die resultate van vorige opnames vergelyk. Die verskille in totale gebiedsdekking en in maasgroottes van nette tussen hierdie en vorige opnames het vergelykende stapelramings uitgesluit. Larwes wat langer as 7 mm is, het die nette bedags vermy, sodat hul onderbemonster is. Larwes was talryk in water van 16-24°C, maar die merendeel wat in water bo 21°C gevang is, was klein (korter as 4 mm). In verskillende gebiede word die voorkoms sowel as oorlewing van larwes deur veranderlike hidrologiese toestande beïnvloed, en drie streke van groter talrykheid, afgebaken deur gebiede met min of geen larwes aanwesig, word geïdentifiseer. By twee geleenthede kon die groeikoers geraam word deur 'n larwe-kohort in agtereenvolgende maande te volg, lengtetoenames van 0,6 mm en 0,9 mm per dag is bereken.

The anchovy *Engraulis capensis* Gilchrist occurs ng the entire coast of South West Africa and ch of that of South Africa too (Pollock 1970). ce 1978, landings of the species in South West ica have exceeded those of the pilchard *dinops ocellata* (Pappe), which has traditionally med the basis of the South West African pelagic hery. The decline in pilchard landings and the ncomitant increase in anchovy landings is ected in Table I.

The decrease in the pilchard stock has resulted more effort being directed towards the anchovy, pecies that ". . . relies so heavily on an extremely iable recruiting year class . . ." (Butterworth d Le Clus 1979, p. 175), that it might become er-exploited if not carefully managed.

In 1978 the Sea Fisheries Institute resumed the tensive ichthyoplankton surveys initially conted off the coast of South West Africa from 72 to 1974. The present surveys are aimed imarily at obtaining information on stock size, tribution and ecology of anchovy and pilchard. A pilot survey was conducted during August 78, during which the area from south of Palgrave int (21°S) to Conception Bay (24°S) was sampled. om October 1978 to April 1979, the South West rican coast from south of the Cunene River °40'S) to Lüderitz (26°40'S) was sampled on a monthly basis. These months coincide with the spawning season of local pelagic fish (King 1977, O'Toole 1977b, Le Clus 1979).

Table I: Landings of pilchard and anchovy caught off South West Africa

Year	Landings (thousands of metric tons)	
	Pilchard	Anchovy
1970	514	189
1971	325	185
1972	374	137
1973	408	296
1974	562	249
1975	561	186
1976	452	88
1977	200	133
1978	46	355
1979	34	278

O'Toole (1977b) reported extensively on the distributional ecology of anchovy larvae, dealing mainly with the aspects of seasonality, geographical distribution, diurnal variations in abundance, distribution related to temperature and salinity, hydrological affinities, growth and dispersal. This report is concerned basically with the same aspects and no estimates of stock sizes are made here.

MATERIAL AND METHODS

Eggs and larvae were collected at the stations shown in Figure 1. Bongo nets similar to those described by King and Robertson (1973) and O'Toole (1977a) were used, assemblage details and sampling procedures given by these authors being adhered to throughout. During this survey, nets with meshes of 0,940 mm and 0,300 mm were used, the latter proving to be more efficient in catching anchovy larvae. At every station, surface salinities and temperatures were recorded and a bathythermograph was sent down to 5 m from the bottom or to a maximum depth of 275m. On lines 46, 58, 70 and 82, subsurface bottle samples were taken in the top 100 m and later analysed for salinity, oxygen and nutrients.

The number of larvae collected at each station was standardized to the number under 10 m^2 of sea surface by the method of Kramer *et al.* (1972). The larvae were identified from descriptions by O'Toole (1977b) and King *et al.* (1978), and standard (caudal) lengths were measured to the nearest millimetre below.

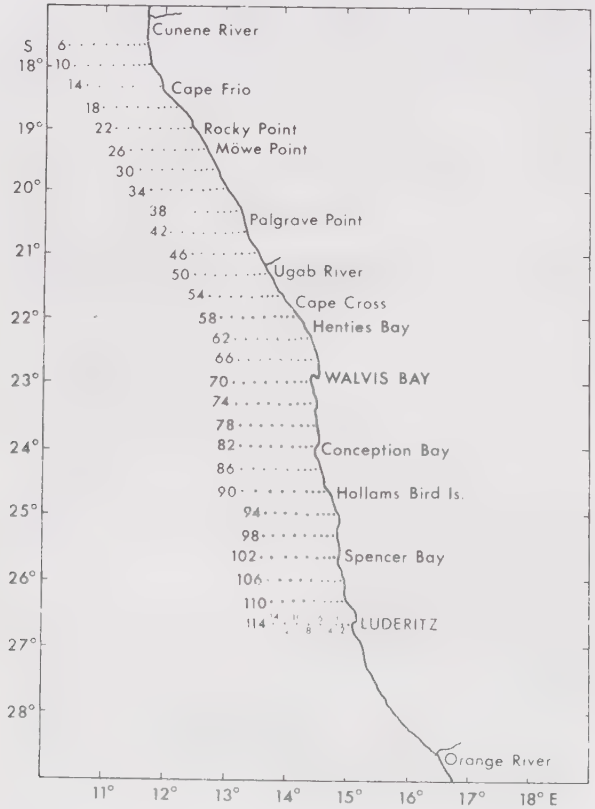


Fig. 1: Routine stations occupied, 1978/79

RESULTS AND DISCUSSION

Catch rates of the two nets

Eighty-nine per cent of all anchovy larvae caught were taken in the 0,300-mm-mesh net. A Kolmogorov-Smirnov comparison (Smith and Richardson 1977) of the length frequency distribution of larvae for the two different mesh sizes throughout the survey is shown in Figure 2. The significant difference level D at the 5-per-cent level of significance was calculated by means of the formula

$$D = \frac{136}{\sqrt{n}} \text{ per cent}$$

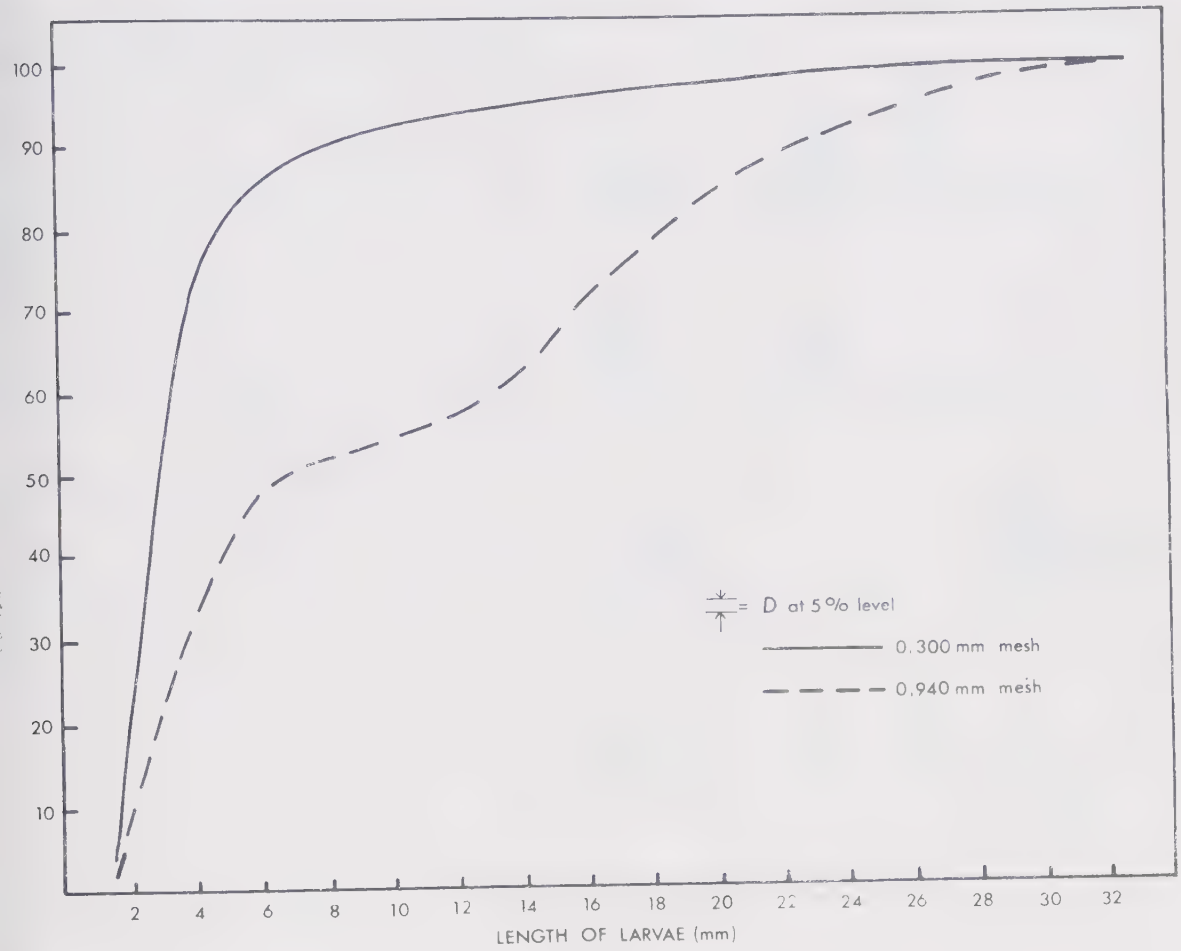
where n = number of sample measurements for the 0,940-mm net.

The value of D was found to be 1,6 per cent. The fact that the two curves differ by more than this percentage is taken as proof that the nets differ significantly with regard to their catch rates.

O'Toole (1977a) compared the efficiency of the two mesh sizes used in his survey (0,940 mm and 0,500 mm) at capturing larvae less than 5 mm long and concluded that there was no significant difference at the 5-per-cent level. A two-tailed Student's *t*-test on paired samples (Zar 1974) was applied to the catch data for all the hauls where larvae less than 5 mm long were caught. It was concluded that the number of larvae less than 5 mm long caught in the 0,940-mm net differed significantly from the number caught in the 0,300 mm net [$t = 3{,}1474$; $0{,}002 < P(t \geqslant 3{,}1474) < 0{,}005$; d.f. = 23].

Diurnal variations in catches

Many authors have noted the undersampling of larvae during the daylight hours. Information on the extent of undersampling of Pacific sardine *Sardinops caerulea* larvae during daylight hours was given by Ahlstrom (1954). He found a relationship between sampling efficiency at certain times and larval length. Ahlstrom (1959) recorded similar results for northern anchovy larvae. For each of these two species, the ratio of larvae



ig. 2 Kolmogorov-Smirnov comparison of sample frequency distribution of larval lengths for the 0,300-mm and 0,940-mm mesh nets, 1978/79

caught in night hauls to larvae caught in day hauls increased linearly with increase in larval length. O'Toole (1977b) reported that over three times as many anchovy larvae were caught in night hauls than in day hauls during the surveys off South West Africa between 1972 and 1974. Data for the 1978/79 survey are given in Table II. Daylight hours are defined as covering the times 06h00 – 18h00, which is an average over the whole period.

Figure 3 shows the percentage catch of three different size categories of larvae over a 24-hour period at two-hourly intervals, combining results from the whole survey. From the figure it is clear that night-time catches of larvae longer than 10 mm

Table II: Comparison of day and night catches of larvae of different length groups

Length group (mm)	Day		Night	
	Number	Percentage	Number	Percentage
< 5	32 960	67,8	15 627	32,2
5–10	3 240	41,3	4 599	58,7
10–15	622	21,2	2 315	78,8
15–20	234	9,2	2 297	90,8
> 20	100	5,2	1 817	94,8
Total	37 156		26 655	

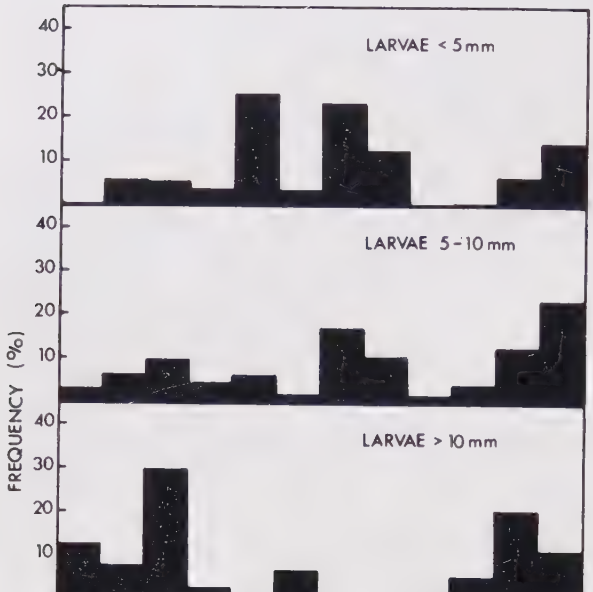


Fig. 3: Diurnal variation in catch rates of larvae in different length categories

were greater than daylight catches. In total more larvae were caught during daylight than during darkness (Table II), but this was thought to have resulted from the occasional exceptionally large catches of smaller larvae, which show little diurnal variation in catch rate. O'Toole (1977b) did not have such a predominance of smaller larvae in his collection and, thus, his day:night ratio of larval capture was not biased.

In order to investigate this problem further, the monthly data by 1-mm length groups were looked at in greater detail and it was found that, in the case of larvae longer than 6 mm, night-time catches were consistently greater than daylight catches during all months, but larvae less than 6 mm long showed no such pattern. In some months, night-time catches of smaller larvae were high, and in others the daylight catches were high, invariably as a result of large concentrations of larvae at one or two stations. O'Toole (1977b) suggested that a positive phototropic reaction may cause small larva to concentrate in patches while feeding in th upper layers during the day, whereas at night the become more passive and sink to deeper layers.

In Figure 4, the number of larvae caught durin the day is compared with the number of larva caught at night. In order to minimize the influenc of patchiness or non-random spatial distributio of the larvae, the number caught at each statio was log-transformed and the geometric mean fo each length group was calculated for day an night samples separately. The adjusted totals fo each length group in both day and night sample were obtained by multiplying the geometric mea of each group by the number of positive sample in that group.

From Figure 4, it is concluded that the daylig and the night-time catches were similar for larva less than 7 mm long. At lengths greater than 7 mm the daylight catches steadily decreased in com parison with the night-time catches and only a few juveniles longer than 22 mm were caught during the day. For the northern anchovy, the length a which metamorphosis takes place and at the onse of schooling is approximately 21,5 mm (Murphy and Clutter 1972). They state, referring to purse seine plankton nets by day, that ". . . a school is more effective than the sum of the individuals in detecting and responding appropriately." (*op. cit.*, p.749). It is felt that this remark would apply equally well to towed plankton nets. Estimates of growth rates of South West African anchovy larvae by O'Toole (1977b) and later in this report compare favourably with those of the northern anchovy, and the same length at metamorphosis is therefore accepted for the South West African anchovy.

The relationship between day:night ratio and larval length can be expressed in the form $y = ax^b \pm$S. E. E., where y is the day: night ratio, x is the larval length, a and b are constants and S. E. E. is the standard error of the estimate. Based on examination of the information in Figure 4, it was decided to omit larvae less than 6,5 mm long and juveniles (longer than 21,5 mm) for the purpose of calculating the regression. The regression yielded a power curve fit of $y = 37{,}18\ x^{-2{,}009} \pm 0{,}1844$, with a coefficient of determination (r^2) of 0,87. The pattern of undersampling during daylight hours is expressed by this regression.

Broad features of distribution in present and past surveys

In the present survey, O'Toole's (1977b) sampling grid was extended by two lines towards the north

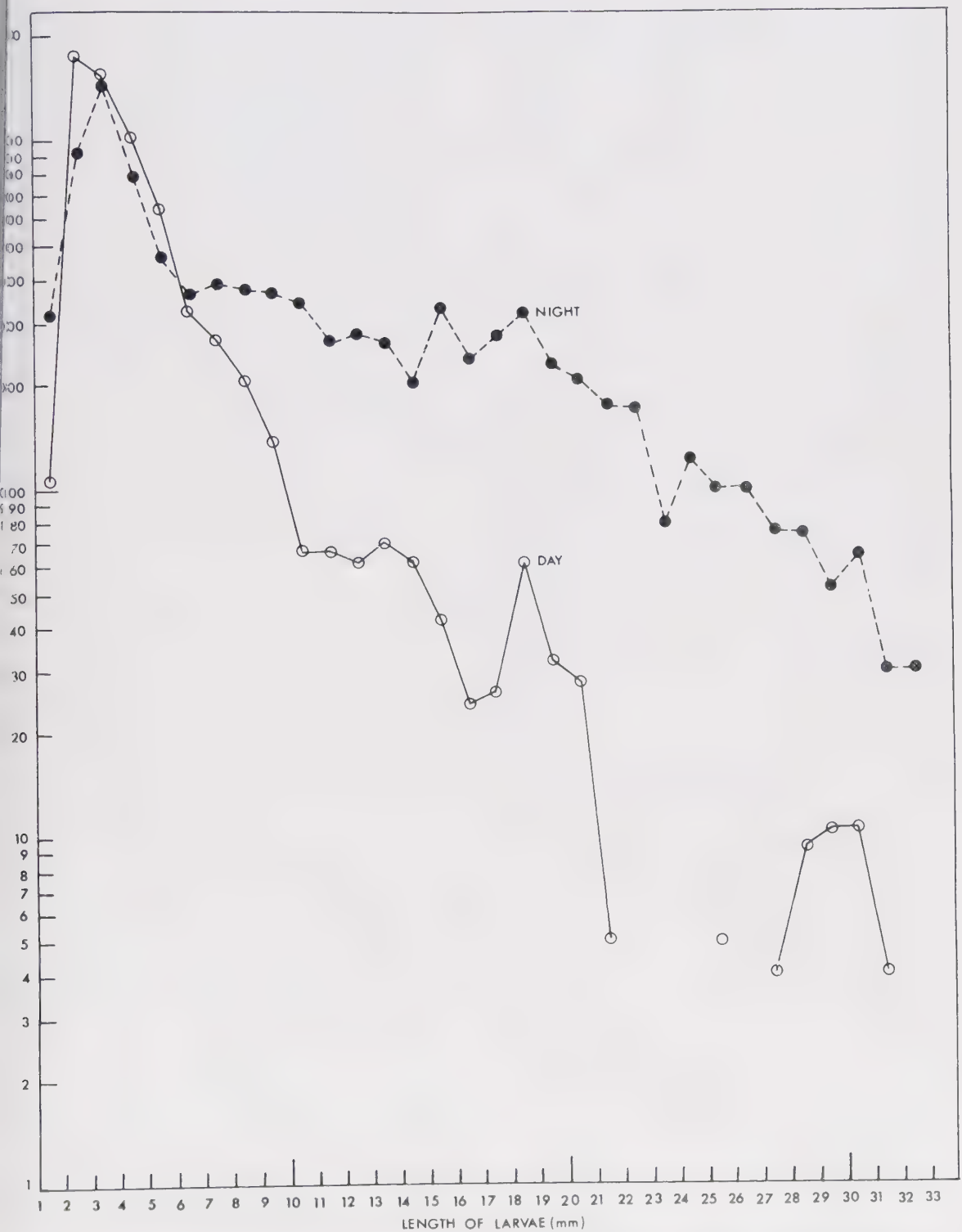


Fig. 4: Comparison of the number of larvae caught during the day (06h00—18h00) and during the night

and by six lines towards the south. The percentages of the total number of anchovy larvae caught in different areas are shown in Table III. Anchovy larvae were widely distributed in the northern sector of the survey area. O'Toole (*op. cit.*) reported that 90 per cent of the larvae caught during the surveys of 1972 — 1974 were taken between Cape Frio and Möwe Point. The two additional lines included in the north accounted for half of the larvae collected during the present survey, and this fact emphasizes the importance of this region. In order to compare the results of this survey with the results of the previous two surveys, the catches on lines 6 — 10 (Cunene River to Cape Frio) and lines 94 — 114 (Hollams Bird Island to Lüderitz) were disregarded. The results after this omission are similar to those of O'Toole (*op. cit.*) for his 1972 — 1974 surveys (Table III).

A preliminary analysis of anchovy egg distribution for the period November 1978 — March 1979 gave an indication that spawning had occurred over a wide range of hydrological conditions between Lüderitz in the south and up to and probably beyond the Cunene River in the north. Anchovy eggs were found to be more dispersed and further off shore in the area south of Walvis Bay. Whether the latter feature was solely the result of the action of currents in that region or because of an instinct on the part of the adult spawners to seek out favourable conditions for survival of eggs and larvae is not known.

On the other hand, areas of larval occurrence seem to be more closely associated with particul hydrological conditions and these were investigate by O'Toole (1977b). The findings in this repo support most of O'Toole's conclusions but, main as a result of the extended sampling grid of th present survey, some new facts are revealed:

(i) Juveniles (25—43 mm long) were regularl found south of Hollams Bird Island in col upwelled water, and it is postulated that the were spawned off the Cape south coast an were transported to their capture locality b currents.

(ii) Larvae were caught over a wider range o surface hydrological conditions than that foun by O'Toole (1977b) and it is suggested that whereas a high salinity and temperatur environment may increase initial larval occur rence, subsequent survival may be low.

(iii) Stable hydrological conditions near the coast which occur regularly in the Henties Bay area (Du Plessis 1967), seem to provide a favourable environment for larvae, as also do the fronta zones mentioned by O'Toole (1977b).

Table III: Comparison of larval capture in various areas (a) 1972—1974 (after O'Toole 1977b), (b) 1978/79 (omitting lines 6—10 and 94—114) and (c) 1978/79 (all lines)

Area	Lines	Percentage of all larvae taken		
		(a)	(b)	(c)
Cunene River to Cape Frio	6—10	—	—	50,3
Cape Frio to Möwe Point	14—26	90,2	81,7	40,5
Möwe Point to Palgrave Point	30—42	8,0	12,7	6,3
Palgrave Point to Henties Bay	46—58	1,7	1,6	0,8
Henties Bay to Sandwich Harbour	62—74	0,1	3,1	1,5
Sandwich Harbour to Hollams Bird Island	78—90	0	0,9	0,4
Hollams Bird Island to Lüderitz	94—114	—	—	0,2

Monthly distribution in relation to the hydrological environment

The monthly distributions of surface temperatures, surface salinities and anchovy larvae are shown in Figures 6—12, and the cumulative distribution of the larvae is shown in Figure 5.

Figure 5 shows maxima of larval abundance in three areas, separated by regions of larval absence (off Hollams Bird Island) or lower occurrence (off the Ugab River). The northern area experienced frontal conditions between Angolan and upwelled water for much of the survey, except during March 1979 when the warm, high-salinity Angolan water covered most of the area. The middle area was covered by lower salinity upwelled water, though surface temperatures were sometimes high, indicating stability. The southern area experienced upwelling conditions for most of the survey duration, higher temperatures only occasionally being recorded off shore.

The frequency distribution of anchovy larvae in the northern region (lines 6—46) is reflected in Table IV, the middle region (lines 50—90) in Table V and the southern region (lines 94—114) in Table VI.

October 1978 (Fig. 6) — During October only three anchovy larvae were collected, north of

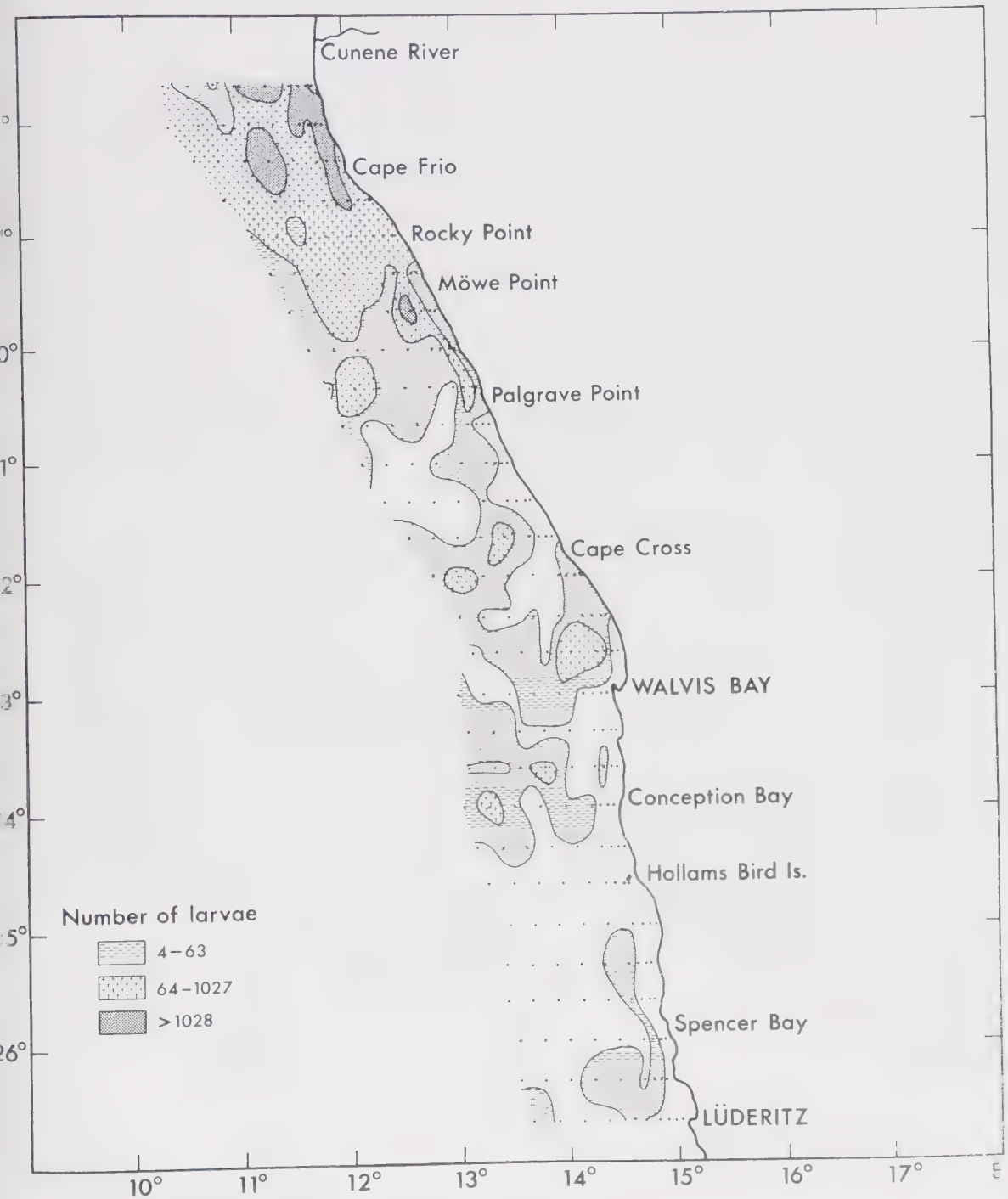


Fig. 5: Cumulative distribution of larvae and juveniles caught during the 1978/79 survey

Table IV: Length frequency distribution in the northern part of the survey area (lines 6–46)

Length group (mm)	Larvae captured													
	November		December		January		February		March		April		Total	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
1–2	1 285	9,7	40	0,9					128	0,5			1 453	2,3
2–3	3 353	25,4	730	17,0	2 093	10,9			9 191	38,1	7	0,8	15 374	24,5
3–4	2 747	20,8	449	10,5	5 976	31,1	40	3,9	10 194	42,3	171	20,7	19 577	31,2
4–5	1 866	14,1	64	1,5	7 927	41,2	125	12,3	1 349	5,6	128	15,5	11 459	18,3
5–6	1 619	12,2	143	3,3	1 231	6,4	150	14,8	562	2,4	37	4,5	3 742	6,0
6–7	850	6,4	97	2,3	60	0,3	25	2,5	434	1,8	8	1,0	1 474	2,4
7–8	138	1,0	43	1,0	116	0,6	15	1,5	444	1,8	13	1,6	769	1,2
8–9	92	0,7	65	1,5	248	1,3	15	1,5	357	1,5	8	1,0	785	1,3
9–10	93	0,7	85	2,0	257	1,3			251	1,0	7	0,8	693	1,1
10–11	53	0,4	156	3,6	159	0,8	8	0,8	183	0,8			559	0,9
11–12	28	0,2	204	4,8	86	0,4			164	0,7			482	0,8
12–13	54	0,4	173	4,0	306	1,6	29	2,9	226	0,9			788	1,3
13–14	34	0,3	239	5,6	41	0,2	31	3,1	134	0,6			479	0,8
14–15	54	0,4	291	6,8	43	0,2	68	6,7	48	0,2			504	0,8
15–16	78	0,6	395	9,2	29	0,2	72	7,1	100	0,4	14	1,7	688	1,1
16–17	49	0,4	299	7,0	32	0,2	86	8,5	53	0,2	19	2,3	538	0,9
17–18	86	0,7	197	4,6	47	0,2	73	7,2	33	0,1			436	0,7
18–19	103	0,8	143	3,3	80	0,4	94	9,3	68	0,3	40	4,8	528	0,8
19–20	112	0,8	99	2,3	19	0,1	37	3,7	66	0,3	25	3,0	358	0,6
20–21	76	0,6	105	2,5	68	0,4	50	4,9	29	0,1	12	1,4	340	0,5
21–22	74	0,6	50	1,2	20	0,1	13	1,3	10	0,0	44	5,3	211	0,3
22–23	97	0,7	13	0,3	27	0,1	24	2,4	11	0,0	53	6,4	225	0,4
23–24	38	0,3	10	0,2	20	0,1	5	0,5	11	0,0	26	3,1	110	0,2
24–25	78	0,6	9	0,2	27	0,1	11	1,1	31	0,1	27	3,3	183	0,3
25–26	102	0,8	19	0,4	42	0,2	9	0,9	6	0,0	38	4,6	216	0,3
26–27	38	0,3	25	0,6	43	0,2	18	1,8	6	0,0	53	6,4	183	0,3
27–28	10	0,1	24	0,6	44	0,2	4	0,4			52	6,3	134	0,2
28–29	5	0,0	18	0,4	44	0,2	10	1,0	7	0,0	8	1,0	92	0,1
29–30	5	0,0	8	0,2	35	0,2					31	3,7	79	0,1
30–31			23	0,5	33	0,2			6	0,0	7	0,8	69	0,1
31–32			20	0,5	21	0,1	3	0,3					44	0,1
32–33			4	0,1	14	0,1							18	0,0
> 33			34	0,8	33	0,1			6	0,0			73	0,1

Length group (mm)	Larvae captured													
	November		December		January		February		March		April		Total	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
1–2									5	1,4			5	0,3
2–3	5	19,2	158	23,6	49	10,1	67	39,2	93	26,0			372	21,8
3–4	15	57,7	123	18,4	62	12,8	42	24,6	198	54,7			440	25,7
4–5			106	15,8	11	2,3			55	15,4			172	10,1
5–6			150	22,4	22	4,5			5	1,4			177	10,4
6–7			87	13,0	22	4,5							109	6,4
7–8	6	23,1	22	3,3	44	9,1	6	3,5					78	4,6
8–9			13	1,9	28	5,8							41	2,4
9–10					41	8,5							41	2,4
10–11					24	5,0							24	1,4
11–12					12	2,5							12	0,7
12–13					38	7,9							38	2,2
13–14			5	0,7	34	7,0							39	2,3
14–15					4	0,8							4	0,2
15–16					21	4,3							21	1,2
16–17					11	2,3	5	2,9					16	0,9
17–18					21	4,3							21	1,2
18–19					11	2,3	5	2,9					16	0,9
19–20					15	3,1	7	4,1					22	1,3
20–21							5	2,9					5	0,3
21–22			5	0,7	5	1,0	11	6,4					21	1,2
22–23					5	1,0	14	8,2					19	1,1
23–24														
24–25							9	5,3					9	0,5
25–33														
> 33					4	0,8			4	1,1			8	0,5

Table VI: Length frequency distribution in the southern part of the survey area (lines 94–114)

Length group (mm)	Larvae captured													
	November		December		January		February		March		April		Total	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
25–26									5	5,8			5	3,8
26–27														
27–28									7	8,1			7	5,3
28–29					3	25			7	8,1	6	25	16	12,0
29–30					9	75			12	14,0	6	25	27	20,3
30–31									20	23,3	6	25	26	19,5
31–32														
32–33	4	100							14	16,3			14	10,5
> 33							11	100	21	24,4	6	25	38	28,6

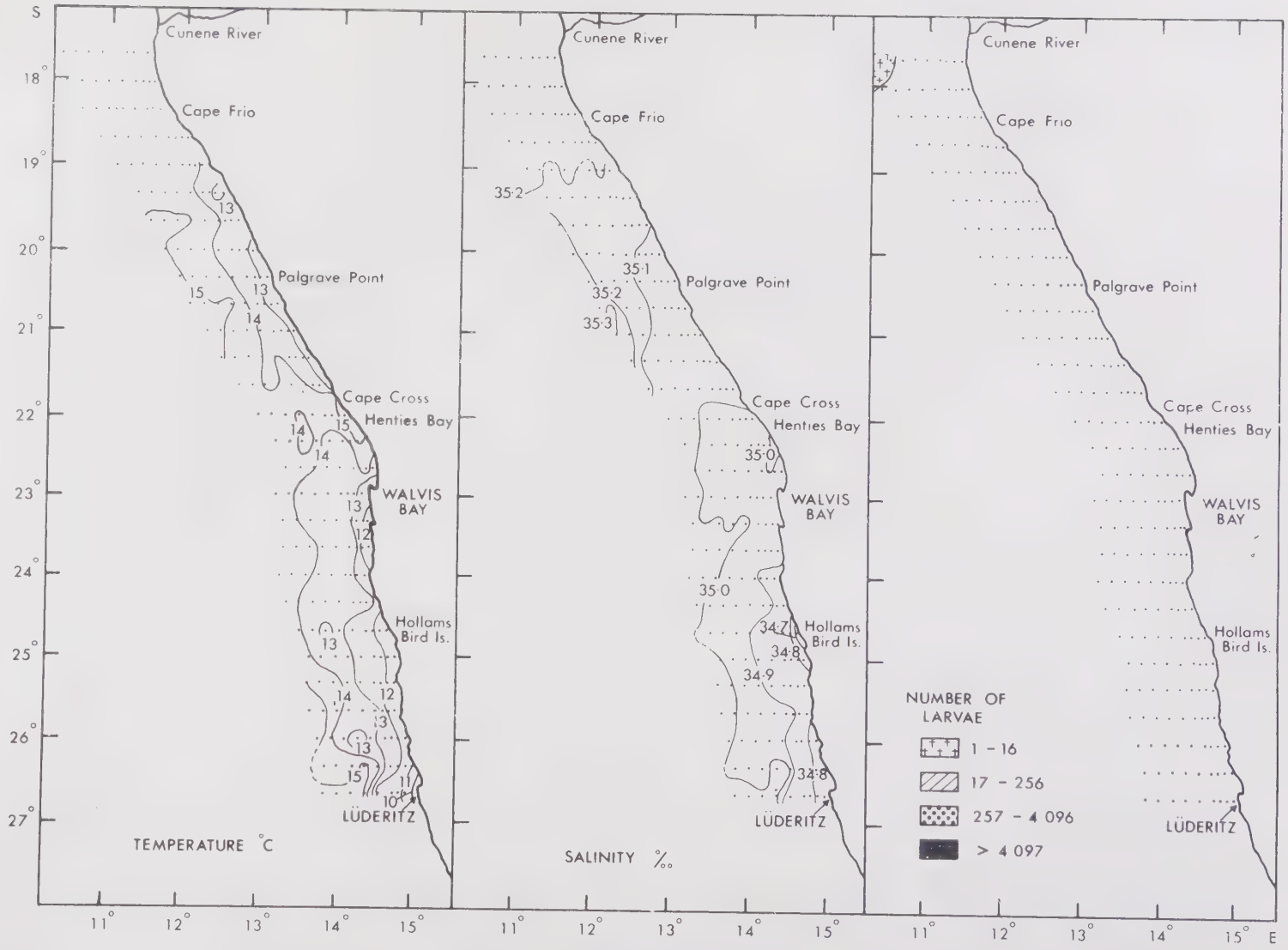


Fig. 6: Surface temperature, surface salinity and larval distribution — October 1972

ape Frio at a distance of 65 miles off shore. All ree larvae were in the 10—11 mm length group. anchovy eggs were found at any station.

Hydrological data are not available for the far rth of the survey area, but the temperature and linity distributions from Rocky Point southwards dicate cool upwelled water extending over most the grid. The off-shore surface water movement sociated with upwelling would have rapidly moved any larvae that might have survived from previous, undetected spawning. However, their ances of survival would be expected to have en low, because anchovy larvae reared in the boratory will not develop normally in water cooler an 14°C (King *et al.* 1978).

ovember 1978 (Fig. 7) — Although, during ovember, eggs were found close inshore from uth of Walvis Bay to the Cunene River, the only ajor concentration of larvae was between the unene River and Cape Frio in high-salinity ngolan water. This body of water had intruded uthwards because of the cessation of upwelling rth of Palgrave Point, and its association with val occurrence has previously been recorded O'Toole (1977b).

Of the 13 263 larvae collected during November, 3 per cent occurred at a single station five miles f shore on the most northerly line of the sampling id. Most of the remainder of the northern group curred within 30 miles of the coast. The larvae re predominantly small, with a modal peak at 5 mm (Table IV). A few larvae were collected in ol upwelled water off shore between Walvis y and Cape Cross (Table V) and also further uth in the Lüderitz area (Table VI).

The cumulative distribution map (Fig. 5) shows e juveniles found south of Hollams Bird Island be distinct from those found further north and, all months, these southern juveniles usually curred in water less than 14°C. Their length istribution also places them apart from the larvae und in other areas (Table VI): they were all nger than 25 mm. This group, which occurred in nuary, February, March and April of 1979 as ell as in November, will be discussed in more etail later.

ecember 1978 (Fig. 8) — Most of the high-linity Angolan water encountered in November the north had retreated and upwelling occurred ong the entire coast, except for two small regions pposite Möwe Point and Rocky Point and a rger area centred around Henties Bay, where a in layer of warm water overlaid cooler water. The latter area regularly experiences more stable thermal conditions than occur to the north or to the south. This is so because of the indentation of the coastline and the presence of a wide continental shelf. Du Plessis (1967) noted this and suggested that the region may give rise to optimum conditions for phytoplankton blooms. In December, both eggs and small larvae (2-7 mm long) were found in this area (Table V and Fig. 8) within 30 miles of the coast, indicating very little dispersion.

Further north, a dense patch of small larvae (1-7 mm long) occurred 15 miles west of Möwe Point in one of the smaller areas of reduced upwelling referred to previously. These small larvae were found just south of December's only other area of major spawning (F. le Clus, Sea Fisheries Institute, personal communication).

The occurrence of eggs and small larvae in areas of reduced or no upwelling seems to indicate that spawning in December may have been favoured in areas where little dispersion could occur.

Still further north and off shore, longer larvae with a modal length of 15,5 mm were encountered and these were probably the remnants of the small larvae sampled in the same area in November, and they are thus fairly well dispersed.

Although only 948 larvae were found during December, the area of occurrence was actually greater than in November. However, if the November station on the northernmost line at which just over 8 000 larvae were collected is excluded, on the grounds that neither in December nor in November was the northern limit of the anchovy distribution sampled, the difference in numbers is slight.

January 1979 (Fig. 9) — Cool water (mainly less than 16°C) prevailed along most of the coast from Lüderitz to Cape Frio. Larvae were found further off shore than in December, except north of Cape Frio where, as was the case in November, many small larvae (2-6 mm long) were found in high-salinity water from the coast to the off-shore grid limits. Of the 19 738 larvae collected during January, 90 per cent were taken in this northern area.

Between Hollams Bird Island and Rocky Point, larvae were found over an extensive off-shore area of more recently upwelled water. In most instances, the separate groups of larvae (Fig. 9) appeared to extend westwards beyond the 65-mile western limit of the sampling grid. The length frequency distribution of the larvae in this area (Table V) is uneven and seven modal peaks are evident, such a high number being anticipated because of the large number of separate patches.

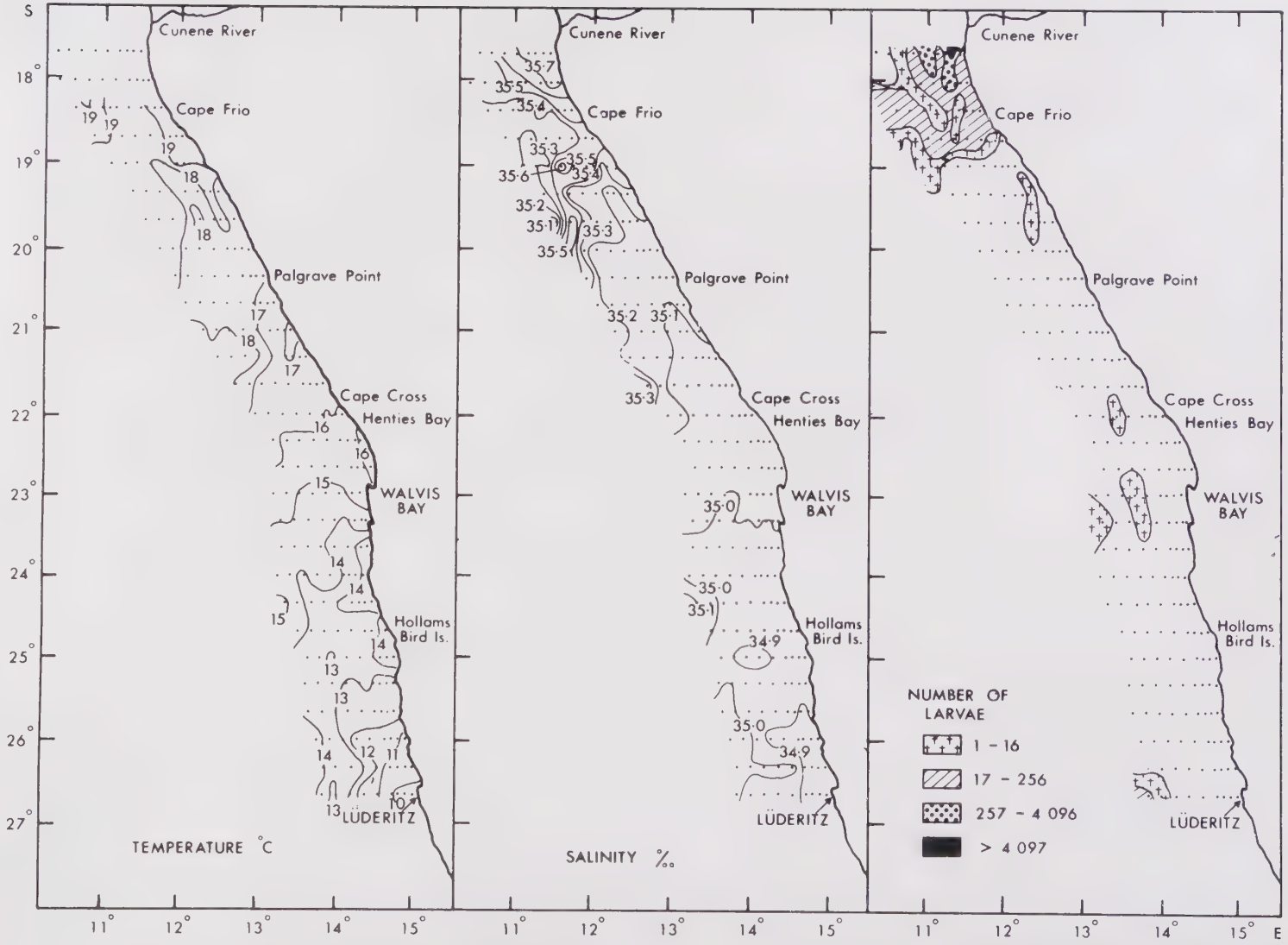


Fig. 7 Surface temperature, surface salinity and larval distribution — November 1972

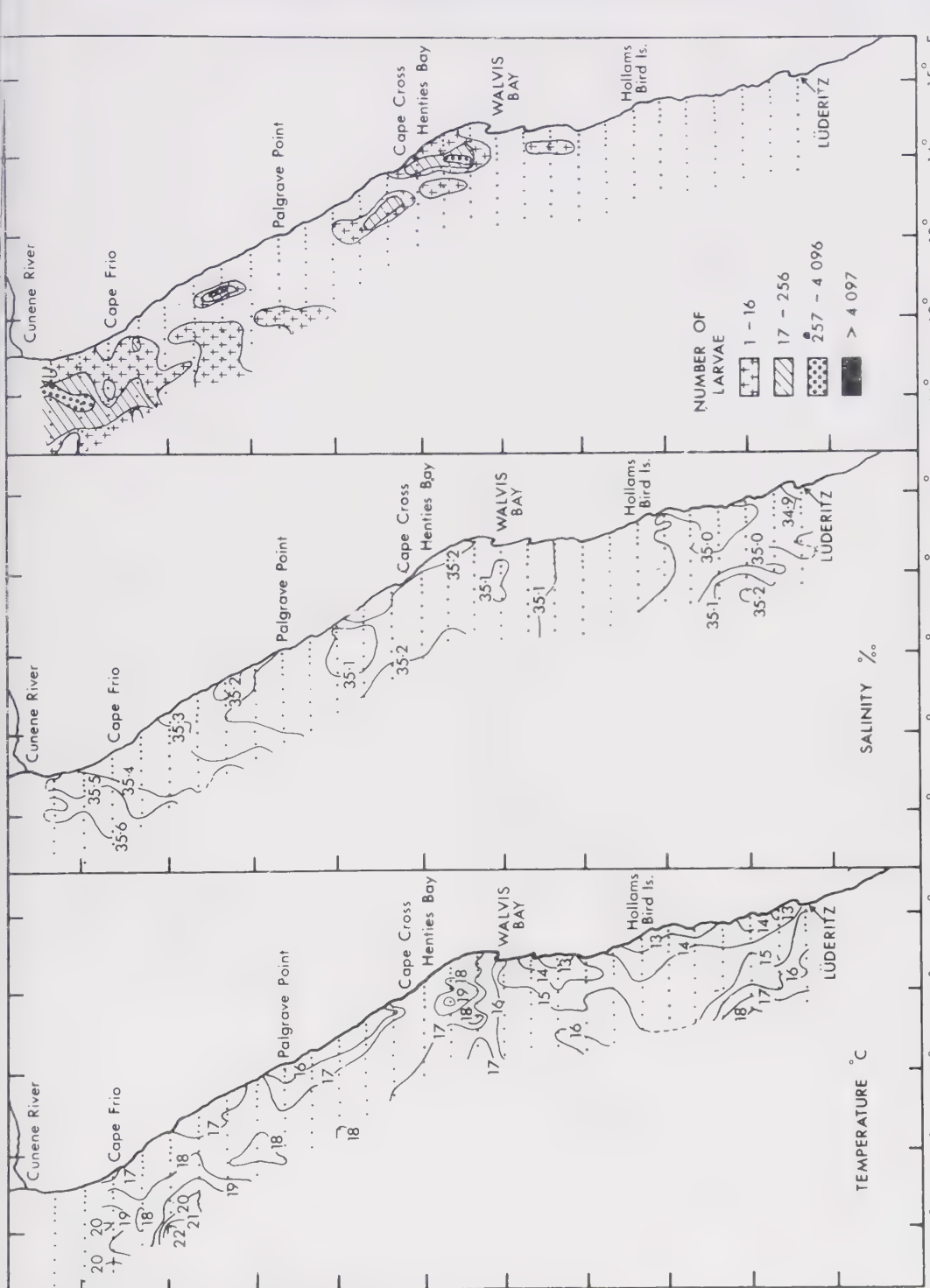


Fig. 8 Surface temperature, surface salinity and larval distribution — December 1978

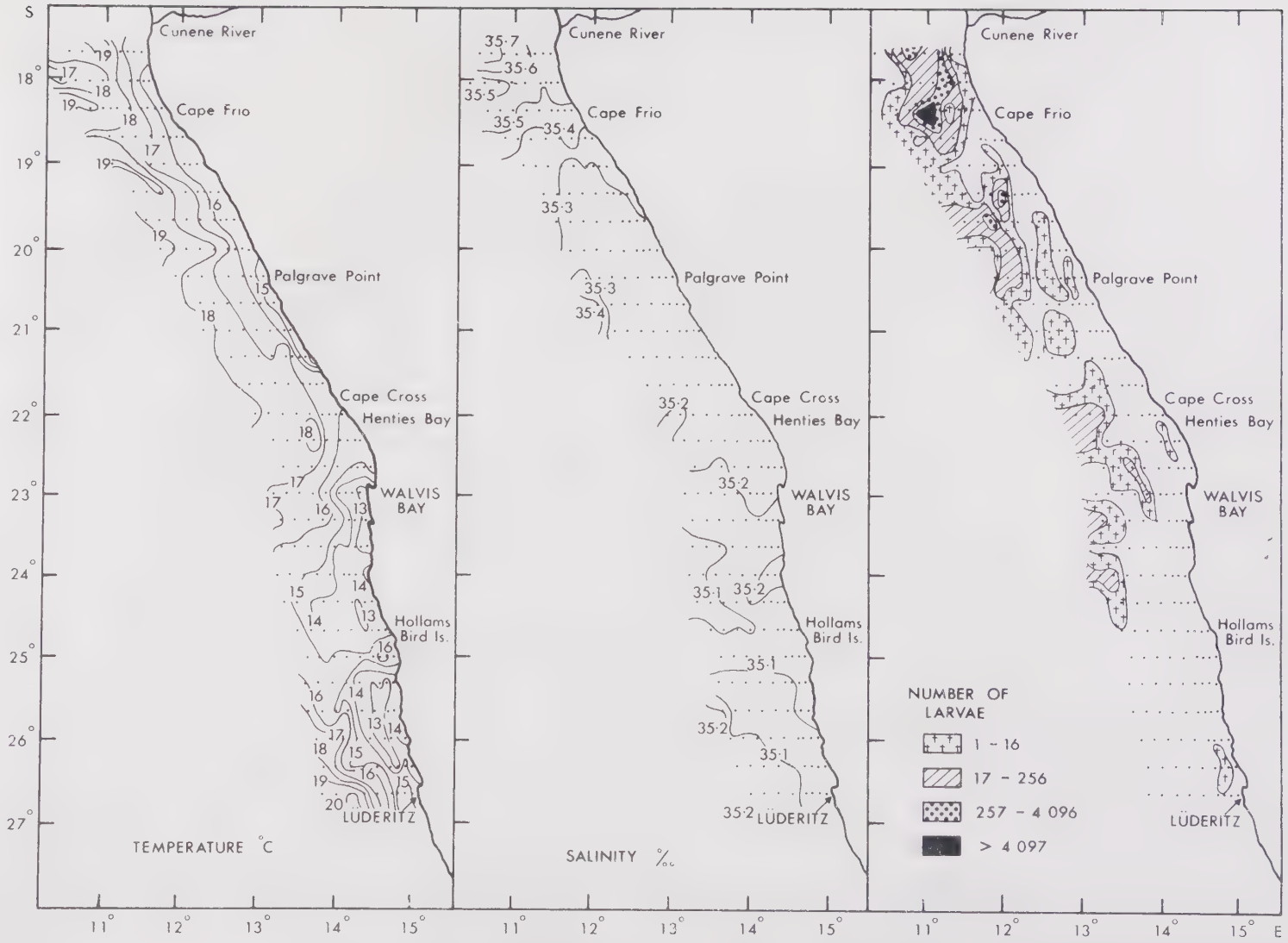


Fig. 9: Surface temperature, surface salinity and larval distribution — January 1979

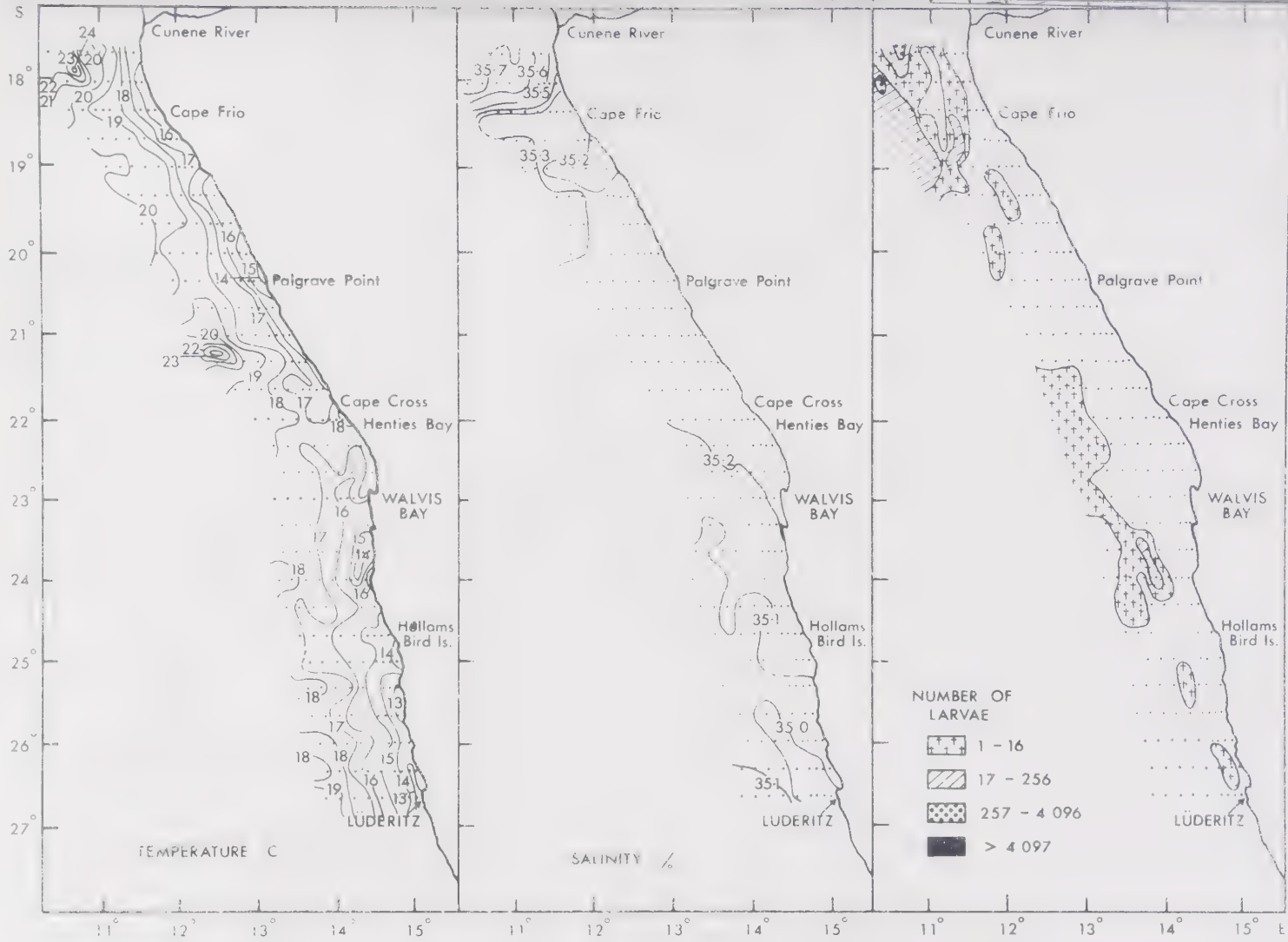


Fig. 10 Surface temperature, surface salinity and larval distribution — February 1979

The older larvae were probably the survivors of those found off Henties Bay in December, in which case larval survival appears to have been good. The smaller ones were the outcome of extensive and heavy spawning south of Walvis Bay.

February 1979 (Fig. 10) — Surface salinity distributions show no major differences between December, January and February with regard to the large-scale hydrology of the survey area, and north of Palgrave Point the areas of larval occurrence during these months are also comparable. However, in February only 1 197 larvae were caught, again mainly north of Cape Frio. Two distinct size ranges were present, the smaller from 3 to 9 mm with a modal peak at 5,5 mm and the other from 12 to 32 mm with a dominant modal peak at 18,5 mm.

From the larval distribution and the hydrological environment north of Palgrave Point in December, January and February, it was noted that very localized patches of larvae, with a larval density up to two orders of magnitude greater than those found at neighbouring stations, may be sampled at a particular station. Such differences in larval density seem to occur without clear-cut hydrological indications, and it is therefore suggested that extreme caution be exercized in drawing conclusions from total numbers of larvae caught in different months with similar hydrology and extent of larval distribution.

March 1979 (Fig. 11) — In March, cessation of upwelling north of Walvis Bay allowed previously restrained Angolan water to invade southwards as far as Palgrave Point.

Examination of bathythermograph traces showed the intrusion had a large vertical extent, particularly inshore in the north (Table VII).

On line 6, within five miles of the coast, water at 20°C extended as deep as 80 m but, further off shore than 15 miles, this water extended only to 25 m. The depth of the 16°C isotherm on lines 6 and 14 was greater than 100 m at 15 miles off shore but 60 m or less at 35 miles. This is compatible with the density structure for a southward-flowing current within 35 miles of the coast.

Altogether 24 552 larvae were caught in March, the vast majority of which were less than 4 mm long. Larvae in the length range 2-4 mm were very abundant between Palgrave Point and line 10 in the north.

The larval distribution in this area shows two features that can be directly related to the hydrology. Firstly, the highest density of larvae is encountered close inshore and this can be ascribed

Table VII: Selected isotherm depths (m) in the northern sector, March 1979

Distance off shore (miles)	Station number	Line 6		Line 14		Line 22
		20°C	16°C	20°C	16°C	16°C
2	1	—	—	10	—	—
5	2	80	—	30	—	No data
10	3	35	—	30	—	80
15	4	25	130	20	110	60
25	6	25	100	25	60	65
35	8	15	50	20	60	65
45	10	20	50	5	50	50
55	12	20	40	5	50	40
65	14	20	50	10	50	45

to the complete cessation of upwelling along the coast, which would normally carry small larvae off shore from where they were spawned. Secondly, the larval distribution is displaced southwards (as well as inshore) in comparison with other months and there appears to be a decline in the density of larvae on the most northerly line. The temperature and larval distributions show that hardly any larvae were encountered in the 26°C water in the far north. Two suppositions appear to be reasonable, namely that water of 26°C is too warm for larval survival, and that, for once, the sampling grid may have sampled the bulk of the anchovy larval stock.

As in December, a warm, stable patch of water off Henties Bay was associated with eggs and small larvae (1-6 mm long) close inshore.

April 1979 (Fig. 12) — Upwelling conditions prevailed along the entire coast and the Angolan water had retreated to the northern off-shore limits of the grid.

Only 852 larvae were caught, 97 per cent from north of Palgrave Point. Two distinct size groups were present in roughly equal proportions, one group of 2-10 mm with a peak at 3,5 mm, and the other ranging from 15 to 31 mm (Table IV). Some of the latter group are, no doubt, survivors of the cohort that supplied 20 000 small larvae to the catches in March.

The fact that so few were caught can be interpreted in two ways. Firstly, many of the surviving larvae may have retreated northwards with the Angolan water, though this is unlikely because the greatest density of larvae were caught off Möwe Point. Secondly, the very warm conditions may have led to very good initial survival through quick development, but lack of suitable food may later have caused massive subsequent mortality.

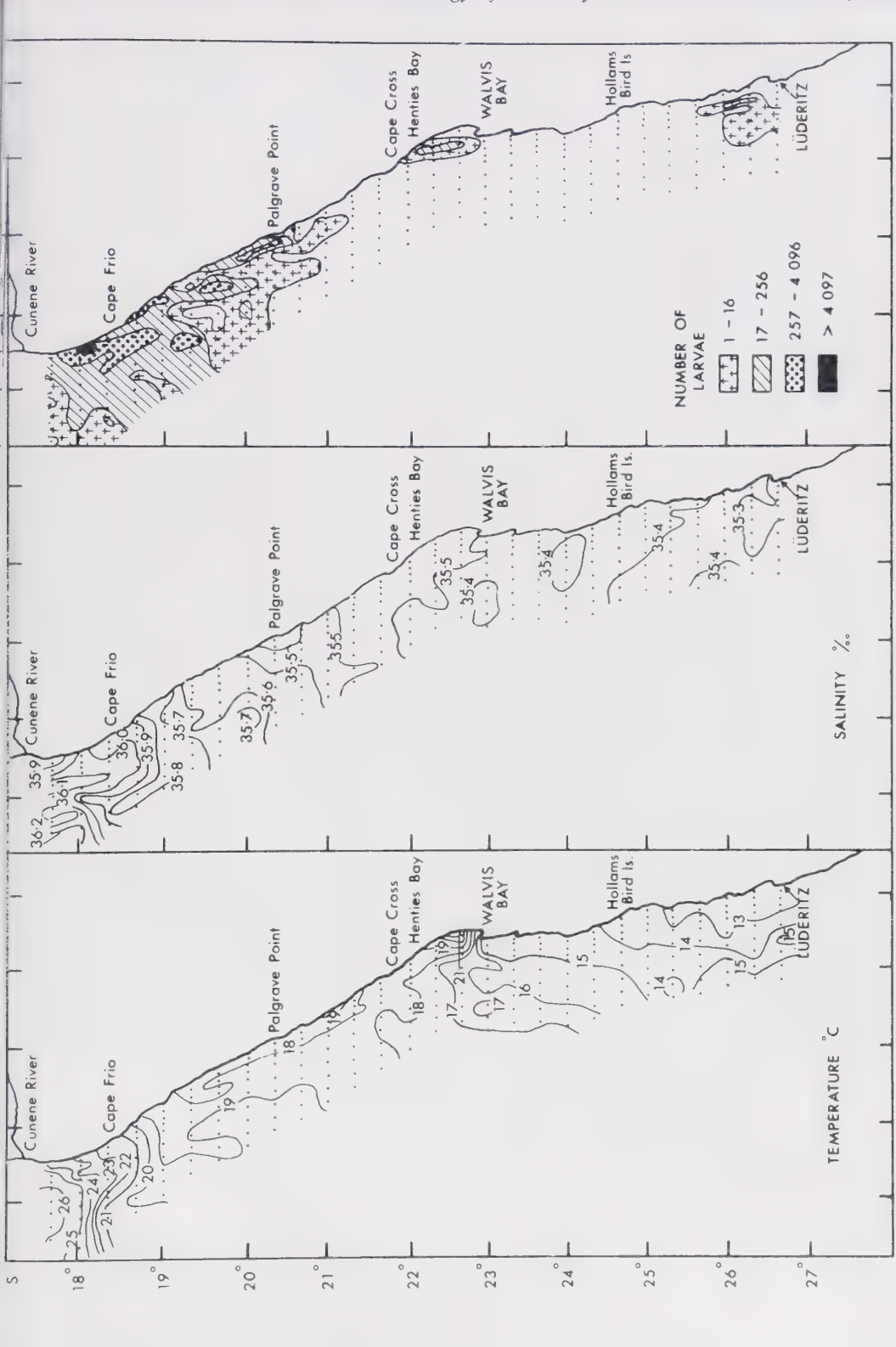


Fig. 11: Surface temperature, surface salinity and larval distribution — March 1979

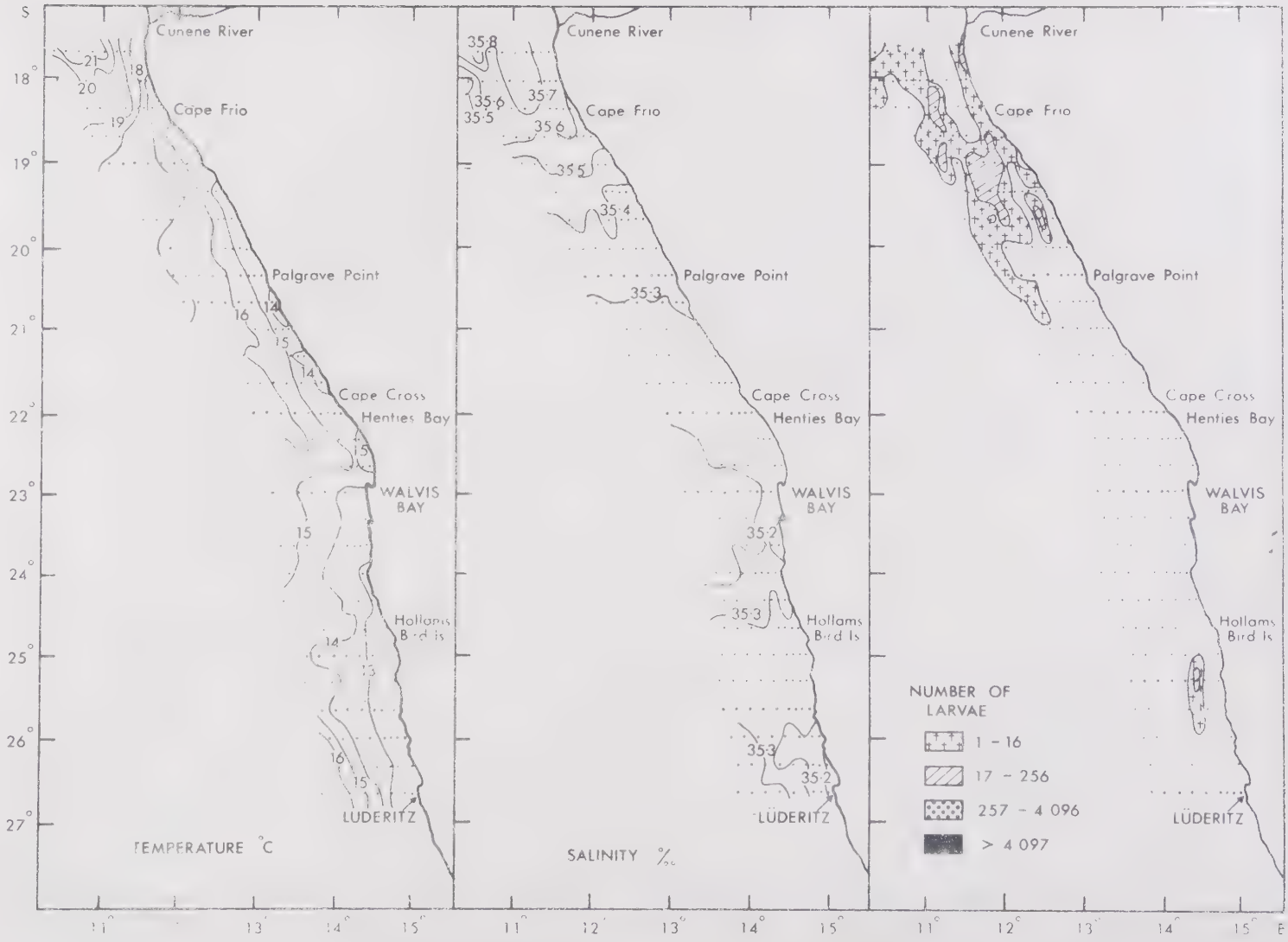


Fig. 12: Surface temperature, surface salinity and larval distribution — April 1979

elton (1979) mentions that, off the South African uth-east coast, westerly winds can blow eggs d larvae eastwards, where they may experience imilar survival pattern. This possiblity is further scussed later.

No larvae were found between Cape Cross and llams Bird Island. However, between Hollams rd Island and Lüderitz, a group of large larvae ain occurred.

arval input into the survey area

As mentioned previously, a length at metamorhosis of 21,5 mm has been accepted for the outh West African anchovy. In subsequent scussion all fish longer than this are therefore eferred to as juveniles.

Isolated patches of juveniles with a minimum ngth of 25 mm occurred between Hollams Bird land and Lüderitz in water with temperatures etween 12 and 16°C in November 1978 and from anuary to April 1979 (Figs. 7 and 9—12). The ngth range of these fish (Table VI) was 25-43 m, corresponding to an approximate age range f 1½ — 2½ months.

Only 133 juveniles were caught in this area uring the whole survey but, of these, 38 (caught five positive hauls) were 33 mm and longer. Of e 64 373 larvae and juveniles caught further orth, only 81 (caught in nine positive hauls) were mm and longer. Therefore, the southern juveniles nstitute a significant proportion of the total venile catch made off South West Africa during is survey.

It is possible that these fish were spawned off e Cape south-east coast and were transported to eir locality off Lüderitz mainly by currents. easons will be presented to show, firstly, that ey could not have been spawned on the West oast north of the Olifants River (31°40′S), where xperimental tows were made on the way to and om the sampling grid, and survived, and, secondly, at current transport is feasible.

The southern juveniles could not have been pawned between Hollams Bird Island and the lifants River because the water is too cold over e greater part of the area most of the time and nchovy larvae do not form a functional jaw in ater of temperature less than 14°C (King *et al.* 978). In addition, not a single larva less than 25 m long was collected during the entire survey in is region.

Also, these juveniles could not have been pawned between Hollams Bird Island and Palgrave Point, because young larvae are generally carried off shore and northwards by the Benguela Current in this area. This is evidenced firstly by the fact that all anchovy eggs found in the survey were within 50 miles of the coast (and they may have been subjected to a day or two's drift before detection), whereas with the exception of the larvae trapped in the Henties Bay — Cape Cross region, larval distributions between Hollams Bird Island and Palgrave Point often appear to extend beyond the 65-mile grid boundary. Secondly, the total absence of any larvae between 25°S and 23°S in March and April 1979 (Figs. 11 and 12), when the southern groups of larvae were strongest, is taken as evidence that no southward migration of northern larvae was in progress. Yelizarov (1967), however, did report a southward-flowing current, which occurred in May 1965 between 23°S and 27°S at a distance of approximately 50 — 80 miles off shore. If larvae were transported southwards, it would have been expected that larvae less than 25 mm long would have been sampled, and also that no area of larval absence would have occurred.

Although larvae spawned between Palgrave Point and the Cunene River may be pushed southwards beyond Palgrave Point by intrusions such as occurred in November 1978 and March 1979, once they were further south the same reasoning given in the previous paragraph would apply.

If these southern juveniles were spawned off the Cape south coast between Cape Point and Cape Infanta they would have to be transported west of Cape Point and then northwards by the Benguela Current, initially at sufficient distance off shore to avoid unfavourable, cold upwelled water. Such transportation appears feasible, because Harris and Shannon (1979) recorded that a satellite-tracked drifter released in early March 1977, 30 miles west of Cape Town (34°S), was positioned about 90 miles west of Lüderitz after 45 days drifting (Fig. 13). The ages of the southern larvae range from approximately 45 to 75 days and, therefore, they would be fully able to venture inshore to areas of higher production.

The transportation of eggs and larvae from the South Coast spawning grounds to the recruiting grounds off the Cape west coast was studied by Shelton (1979). The path of transportation was close to the outside of the front between upwelled and oceanic water, and the 137-km distance from the South Coast to the West Coast was covered in under three days (Fig. 13).

Further work (P. A. Shelton and S. L. Davies, Sea Fisheries Institute, personal communication) shows Cape-spawned larvae being transported off

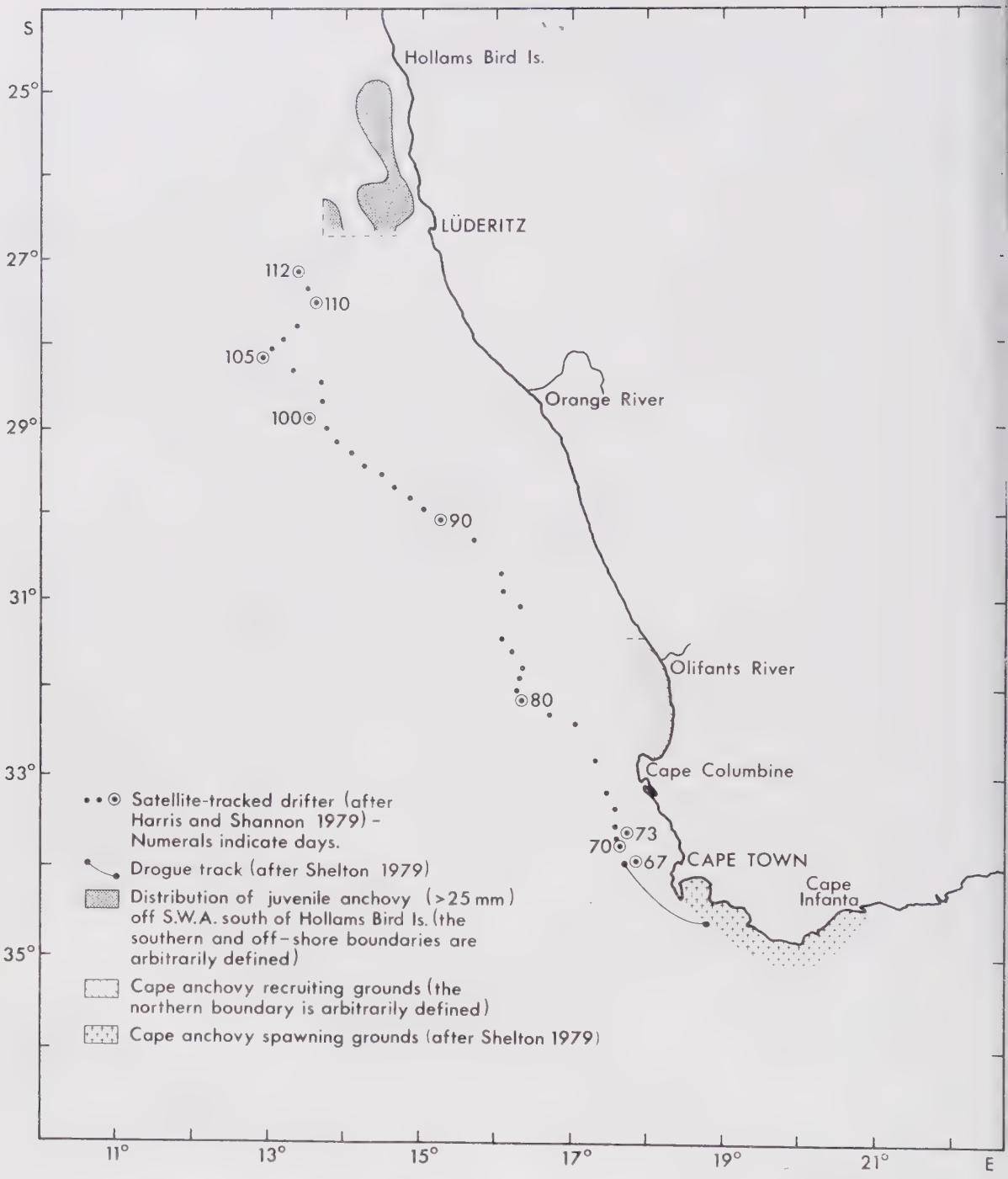


Fig. 13: Spawning and recruiting grounds off the south and west coasts of South Africa, distribution of juveniles between Lüderitz and Hollams Bird Island and a possible transport path deduced from the tracks of a satellite-tracked drifter and a drogue

Table VIII: Abundance of larvae related to temperature

Surface temperature (°C)	Number of standard hauls that collected					Total positive hauls	Total number of larvae collected
	1—5 larvae	6—10 larvae	11—100 larvae	101—250 larvae	> 250 larvae		
12,1—13,0	1	2	2	0	0	5	77
13,1—14,0	1	3	2	0	0	6	63
14,1—15,0	3	1	3	0	0	7	56
15,1—16,0	6	4	6	1	1	18	682
16,1—17,0	5	10	8	1	3	27	4 236
17,1—18,0	15	8	35	6	5	69	5 087
18,1—19,0	9	14	18	7	8	56	19 048
19,1—20,0	3	10	18	5	4	40	2 851
20,1—21,0	0	1	7	4	5	17	10 992
21,1—22,0	0	1	3	2	6	12	7 347
22,1—23,0	0	1	3	1	1	6	6 654
23,1—24,0	0	0	1	0	2	3	6 204
24,1—25,0	1	0	1	0	0	2	47
25,1—26,0	0	0	6	1	0	7	480
26,1—27,0	1	1	1	0	0	3	23

hore and northwards beyond the limits of the Cape Egg and Larva Programme (CELP) survey grid, to a position approximately 60 miles west of Cape Columbine. Generally, few larvae are detected n the Cape recruiting grounds, also shown in Figure 13. Yet at some stage, which is probably letermined in part by the occurrence of an oceanic ntrusion following a relaxation of upwelling, larvae nust come inshore and mix within the colder water along the coast. Because juveniles were ound from south of Hollams Bird Island to the Olifants River, the inshore migration may occur ver an extensive area. Unfortunately, the area etween Lüderitz and the Olifants River was not urveyed in sufficient detail to clarify the larval istribution.

Whether the large larvae found off Lüderitz eturn to the Cape or recruit into the South West African fishery is unknown. If the latter is the ase, it does supply an explanation as to the origin of the juvenile population that materializes off Walvis Bay in June and July.

Hydrological affinities of larvae

Anchovy larvae were captured over a much wider range of surface temperature and salinity conditions than found by O'Toole (1977b). He found 77 per cent of all larvae in water with surface temperature of 18 — 21°C, and only 3 per cent in water with temperatures above 21°C. The corresponding figures from this study are 51 and 32 per cent respectively, and Table VIII shows the abundance of larvae in the 21—24°C range. These temperatures are typical of Angolan water before mixing with Benguela Current water has taken place. This increase in the percentage of larvae caught in high temperature (and salinity) water is a direct result of the extension of the grid to include two lines north of Cape Frio.

The contribution of larvae captured in water with surface temperature lower than 15°C is insignificant numerically, but important in that they constitute about 25 per cent of all juveniles longer than 33 mm captured off South West Africa.

In both O'Toole's (1977b) study and in the present one. the greatest number of positive hauls was made in the 17,1—18,0°C temperature range, although the number of larvae captured in this range was less than 10 per cent of the total. This 17—18°C water is neither newly upwelled nor Angolan in origin, and larvae in it would usually be dispersed as a result of mixing. In the water between 21 and 24°C, however, not as many positive hauls were made and yet four times as many larvae were captured. Similarly, the greatest number of positive hauls was made in the 35,21—35,30‰ salinity range (Table IX), but the total number of larvae caught in water of higher salinity is much greater. In contrast, O'Toole (*op. cit*) reported most positive hauls in the 35,41—35,50 ‰ range.

These findings can be ascribed to the facts that, firstly, water between 17 and 18°C covered a far greater area than water above 21°C and, secondly, patches of very high larval density frequented water of high temperature and salinity. This patchiness in turn implies a very high proportion

Table IX: Abundance of larvae related to salinity

Surface salinity (‰)	Number of standard hauls that collected					Total positive hauls	Total number of larvae collected
	1–5 larvae	6–10 larvae	11–100 larvae	101–250 larvae	250 larvae		
34,51–34,60	1	0	0	0	0	1	3
34,61–34,70	0	0	0	0	0	0	0
34,71–34,80	1	1	1	0	0	3	37
34,81–34,90	0	0	0	0	0	0	0
34,91–35,00	1	0	1	0	0	2	19
35,01–35,10	6	3	3	1	0	13	217
35,11–35,20	7	6	14	0	1	28	1 051
35,21–35,30	11	11	18	3	3	46	3 090
35,31–35,40	3	7	13	2	1	26	1 161
35,41–35,50	6	4	15	4	1	30	9 994
35,51–35,60	3	10	16	3	7	39	11 163
35,61–35,70	3	7	9	5	7	31	4 637
35,71–35,80	0	2	11	6	4	23	13 560
35,81–35,90	0	1	2	1	1	5	757
35,91–36,00	0	0	3	2	4	9	3 596
36,01–36,10	1	1	3	1	5	11	14 838
36,11–36,20	0	0	2	0	0	2	32
36,21–36,30	0	0	3	0	0	3	129

of small larvae, because little time has elapsed to allow dispersal.

Almost twice as many larvae were caught in the 18–19°C temperature range as in any other, but water of this temperature is allied with various salinity conditions in various areas. Table IX shows three salinity ranges with distinct simultaneous submaxima in both the total number of positive hauls and the total number of larvae collected in a range. These occur at 35,21–35,30 ‰ and 35,51–35,60‰, both associated with the water of 18–19°C, and at 36,01–36,10 ‰, associated with water warmer than 21°C.

It can be seen from the cumulative larval distribution (Fig. 5) and from the salinity distributions for the various months that the first range covers most larvae found in Benguela Current water and includes the larvae occurring in the Henties Bay area. The other two salinity ranges were encountered north of the Ugab river. The second range is typical of conditions between Angolan and Benguela Current water when upwelling to the south and inshore creates a front.

The third and highest salinity range 36,01–36,10‰ belongs to undiluted Angolan water, i.e. associated with temperatures of more than 21°C, and was only encountered off South West Africa in March. Although extremely high larval densities over a wide area were associated with this intrusion, in part possibly because hatching in 22°C water takes one day instead of the two taken at 17°C (King *et al.* 1978), not many larvae were encountered in April, indicating poor subsequent survival. It is relevant to note that more than 80 per cent of the larvae found in March were less than 4 mm long, and according to the growth rates reported by King *et al.* (*op. cit.*) they would not yet have fed.

Growth rate of larvae

An estimate of the growth rate of anchovy larvae was made by attempting to follow a cohort sampled in November 1978 in the northern part of the survey area, in which a distinct group of larvae ranging from 1 to 7 mm long with a modal peak at 2,5 mm (Table IV) was caught. The same area was sampled 14 days later, and the frequency distribution of the larvae caught (during the December 1979 survey) shows two distinct size groups (Table IV), the second ranging from 10 to 20 mm in length with a modal peak at 15,5 mm. This latter group presumably represents the remnants of the cohort sampled during November. The growth rate would therefore be approximately 13 mm in 14 days or 0,9 mm per day, which is somewhat higher than the estimate of 0,5–0,6 mm per day by O'Toole

1977b).

Between the November and December cruises, however, the hydrology of the area had undergone changes, such as the recommencement of upwelling along the coast and the retreat of the Angolan front. The probability that the same cohort had been sampled was therefore lower than had been hoped.

A second cohort was followed from January 1979 to February 1979, again in the northern area. A distinct group of larvae, 2—6 mm long with a modal peak of 4,5 mm, was present during January (Table IV). When the same area was sampled 23 days later, two size groups were present. The second group, ranging from 12 to 32 mm long with a modal peak of 18,5 mm, was assumed to be the remnants of the cohort sampled in January. Hydrological conditions were similar on these two surveys and it is therefore considered likely that the same cohort had been sampled. An increase in length of approximately 14 mm over a period of 23 days or 0,6 mm per day is indicated, which agrees favourably with the findings of O'Toole (1977b).

Age determination of 13 individual anchovy larvae by counting the day-rings on their otoliths has recently been carried out by R. M. Thomas (Sea Fisheries Institute, personal communication). Larvae between 21 and 25 mm long were found to be 33—52 days older than at the time of otolith formation (assumed to be at ± 10 days). All larvae with more than 42 day-rings came from a station to the south of Lüderitz and would have grown in generally cold conditions, whereas those with fewer than 42 day-rings were collected at a northern station and therefore would have had a history of a warmer environment. The growth rate of the larvae caught in warmer water would be approximately 0,5 mm per day and those caught in cooler water, 0,4 mm per day. Therefore, the daily growth rate of 0,5—0,6 mm calculated by O'Toole (1977b) and in this report for the January 1979 cohort in the northern area appears reasonable.

CONCLUSIONS

The nets (mesh sizes 0,300 mm and 0,940 mm) used during the survey differed dramatically in their catch rates, and it is recommended that a smaller mesh should be paired with the 0,300-mm net in future surveys.

No quantitative comparisons between this survey and the two previous surveys, when initially two 0,940-mm-mesh nets and later a 0,940 mm and a 0,500-mm-mesh net were used, can be made before methods of standardization of the catches of the first two surveys to a 0,300-mm-mesh standard have been developed.

A relationship between the ratio of numbers of larvae caught during the day to the number caught during the night and larval length has been noted. Larger larvae exhibited a greater tendency to avoid the nets during the day than did the smaller larvae. The resultant non-representative sampling of the larger larvae would underestimate larval survival and, therefore, no quantitative estimates of larval mortality have been made.

With regard to the influence of the hydrological environment on the larval distribution, this study supports the following conclusions:

(i) Larvae spawned off the Cape south coast are transported northwards by currents to an area extending as far north as Hollams Bird Island. As juveniles, they constitute 32 per cent of all anchovy longer than 33 mm caught off South West Africa during this survey.

(ii) Larvae were found to occur abundantly in water of surface temperature up to 24°C. The majority of larvae found in water 21°C and higher were small (less than 4 mm long) and had yet to feed. Subsequent low numbers of larger larvae in the same areas indicate that their survival chances were poor. Larvae occurring in warm water on the northern side of the front between Angolan and upwelled water contributed by far the majority of all larvae and juveniles sampled during this survey. This agrees with the findings of O'Toole (1977b).

(iii) Favoured larval occurrence in the Henties Bay area was noted in conjunction with stable hydrological conditions, and survival chances in this area appeared to be good.

In summary, three reasonably distinct areas of larval occurrence are recorded, one south of Hollams Bird Island, one between Walvis Bay and Cape Cross, and one north of Palgrave Point with most larvae north of Cape Frio. However, results from this survey show that intensity of spawning is similar from Walvis Bay northwards. The hydrology therefore appears to be responsible for the differences in larval abundance and for apparently different survival probabilities of larvae.

ACKNOWLEDGEMENTS

We wish to thank Mr B. Rose and his technical staff, especially Miss G. G. Henkel, who identified and measured all the larvae, and Dr L. Hutchings and Messrs A. I. L. Payne, P. A. Shelton and G. E. Venter for constructive criticism of the manuscript. Fruitful discussions held with Dr D. S. Butterworth and Miss F. le Clus are gratefully acknowledged.

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SURFACE DRIFT AND THE DISTRIBUTION OF PELAGIC-FISH EGGS AND LARVAE OFF THE SOUTH-EAST COAST OF SOUTH AFRICA, NOVEMBER AND DECEMBER 1976

P. A. SHELTON and F. KRIEL

Surface drift cards were released in shallow water between Cape Town and Port Alfred in early summer 1976. Two wind regimes, south-east and north-west, led to northward and westward and to eastward drift respectively. Surface net tows yielded anchovy eggs and larvae over most of the area. Anchovy eggs and larvae would be transported by the south-east wind regime, which is dominant during the main spawning season east of Cape Point, to upwelling areas on the West Coast favourable to development. In contrast, north-west winds would result in their transportation to unfavourable areas.

Gedurende die voorsomer 1976 is oppervlakdryfkaarte in vlak water tussen Kaapstad en Port Alfred gelos. Twee windstelsels, suidoos en noordwes, het onderskeidelik tot noord- en weswaartse, en tot ooswaartse dryfverspreiding gelei. In die grootste deel van die gebied het oppervlaktreknette ansjoviseiers en -larwes opgelewer. Ansjoviseiers en -larwes sou tydens die vernaamste kuitskietseisoen oos van Kaappunt deur die heersende suidoostewind vervoer word na opwelgebiede aan die Weskus, waar gunstige ontwikkelingstoestande heers. Daarteenoor sou noordwestewinde daartoe lei dat hulle na ongunstige gebiede vervoer word.

Experimental fishing by the purse-seiner *Hoëveld* during November and December 1976 presented the opportunity to examine surface drift and the distribution of fish eggs between Cape Town and Port Alfred. At stations 1—24 (Figure 1a) surface water temperature was measured and a 10-minute surface tow was made with an EES-52 net (King and Robertson 1973) of 300 μm mesh. At stations 1—25 batches of 25 plastic drift cards, as described by Shannon *et al.* (1973), were released.

Recovery of drift cards was rapid because of the coincidence of the cruise with the summer holiday season. Therefore, drift-card movements tend to reflect recent events and can give an indication of minimum current speeds. A north-westerly gale (winds exceeding 20 m.sec^{-1}) was experienced between stations 1 and 7 with a more moderate breeze (about 10 m.sec^{-1}) further east. Associated with this was an eastward drift of water at stations 1—15 (Fig. 1 b, c). The mean minimum drift speed of cards in the area between Cape Point and Knysna recovered within 50 days of release was 0,122 m.sec^{-1} (n = 12, SD = 0,071). From Knysna to Port Alfred, the mean minimum drift speed was higher (0,214 m.sec^{-1}) but there was more variation around the mean (n = 15, SD = 0,187).

At station 16 (Fig. 1b) drift was westward. Cards released at station 17 followed the eastward pattern and were found beyond Port Alfred, whereas cards released further inshore at station 18 showed no single current direction (Fig. 1c).

From stations 19 to 25, drift was westward around Cape Agulhas and northward past St Helena Bay (Fig. 1c). This movement was associated with strong south-east winds.

Four drift cards released at station 25 were recovered in the vicinity of Doring Bay approximately 320 km away. The first of these four cards was found 11 days after release, indicating a minimum current speed of 0,33 m.sec^{-1}. This is slower than the average speed of 0,55 m.sec^{-1} for a parachute drogue adjusted to follow water at 10 m depths and released in the vicinity of Cape Point (Shelton 1979) during a period of south-east wind.

Movements of surface drift cards are considered to be subject to actual water movements rather than to the direct action of the winds (Duncan and Nell 1969). The reversal in the surface-drift pattern associated with a reversal in the direction of the wind points to a wind-induced current mechanism rather than to the direct effect of the wind on the cards. The direction of surface drift under south-east wind conditions supports the summer trends found by Duncan and Nell (*op. cit.*), whereas the eastward flow during north-west wind is consistent with their winter conditions.

The presence of pilchard *Sardinops ocellata* and round-herring *Etrumeus teres* eggs and larvae along the East Coast (Table I) shows that the Cape Egg and Larva Programme (CELP), which extended as far east as Cape Barracouta, did not encompass the entire spawning range of these species, reaffirming the finding of Anders (1975).

The distribution of anchovy *Engraulis capensis*

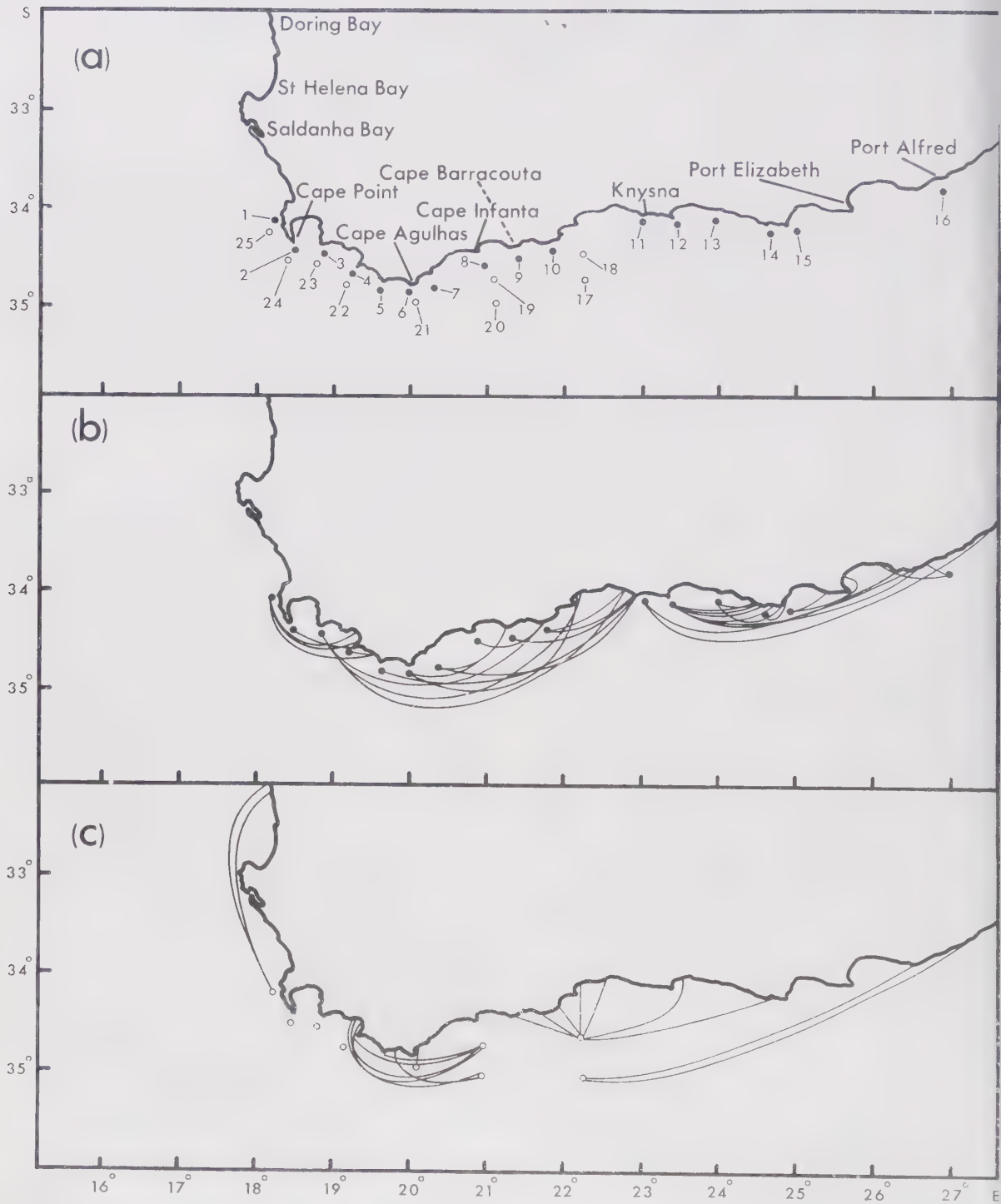

Fig. 1: (a) Position of stations surveyed by M. F. V. *Hoeveld* in November and December 1976 (black and open circles represent the outward and return trips respectively). (b) Direction of drift from cards released on the outward and (c) return trips

Table 1: Surface temperature and the abundance of eggs and larvae of three fish species in a 10-minute surface tow with an EES-52 net off the South-East Coast

Station number	Surface temperature (°C)	Anchovy		Pilchard		Round-herring	
		Eggs	Larvae	Eggs	Larvae	Eggs	Larvae
1	16,6	99	1	0	0	0	0
2	16,6	4	1	0	0	7	0
3	17,6	18	0	0	0	0	0
4	17,0	27	3	0	0	3	0
5	17,0	1	0	0	0	0	0
6	18,3	1	0	0	0	2	0
7	19,8	2	0	0	0	1	0
8	19,3	0	0	0	0	0	0
9	20,3	0	0	0	0	0	0
10	20,3	0	0	1	1	102	1
11	22,8	0	0	0	0	0	0
12	21,3	0	0	2	0	17	0
13	20,0	0	0	0	0	0	0
14	19,8	0	0	4	0	41	0
15	22,5	0	15	29	0	104	2
16	20,6	0	0	0	0	6	0
17	20,3	0	0	0	0	0	0
18	19,7	0	0	0	0	2	0
19	17,6	893	0	0	0	3	1
20	17,3	0	138	1	0	6	0
21	17,3	35	3	0	0	5	3
22	17,5	1 588	0	194	0	6	0
23	17,5	448	2	0	0	3	2
24	16,5	2 608	5	0	0	1	0

ggs and larvae between Cape Point and Cape Agulhas is similar to the distribution recorded 10 days later by Shelton (1979). Anchovy larvae found far east of the eggs, at station 15, ranged in length (tip of snout to end of notochord) from 9,0 to 13,0 mm and may have drifted from the spawning area, a length at hatching of 2,48—3,20 mm (King *et al.* 1978) being accepted.

Anchovy larvae carried eastwards into warm water would experience rapid development compared with larvae in the cold upwelling region. However, the lower productivity of the water would presumably cause food particles to be scarcer and mortality to be relatively higher.

Eggs spawned between Cape Point and Cape Agulhas during normal summer south-east wind conditions would be carried rapidly up the West Coast into upwelling waters and survival would be expected to be high.

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OCCURRENCE AND DISTRIBUTION OF LANTERN-FISH *LAMPANYCTODES HECTORIS* CATCHES IN THE SOUTH AFRICAN PURSE-SEINE FISHERY, 1968—1976

R. J. M CRAWFORD

The annual contribution of lantern-fish *Lampanyctodes hectoris* to South African purse-seine landings in the Western Cape has shown wide fluctuations. A maximum of 42 368 metric tons was recorded in 1973. Most catches have been made between the Olifants River and Dassen Island during the first four months of the year. Off Cape Columbine, at the head of the Cape Canyon, catches have been particularly good. Here the bottom topography may be expected to divert sub-surface currents upwards and could influence the vertical location of lantern-fish in the water column, so making them available to purse-seiners. Catches have been dominated by females and have generally covered a narrow length range of mainly immature fish. Length and length-mass relationships are presented.

Die jaarlikse bydrae deur lanternvis *Lampanyctodes hectoris* tot die beursnetvangste in die Weskaap aan wal gebring het groot skommelinge getoon. In 1973 is 'n maksimum van 42 369 metrieke ton aangeteken. Die meeste vangste is gedurende die eerste vier maande van die jaar tussen die Olifantsrivier en Dasseneiland gemaak. Digby Kaap Columbine, aan die bo-ent van die Kaapse Canyon, was vangste besonder goed. In hierdie gebied kan verwag word dat die bodemtopografie die sub-oppervlaktestrome boontoe deflekteer en sodoende die vertikale ligging wat lanternvis in die waterkolom inneem, beïnvloed en hul vir beursnetbote toeganklik maak. 'n Klein lengtebestek van hoofsaaklik onvolwasse vis is waargeneem in die vangste, wat oorwegend uit wyfies bestaan het. Lengte- en lengte-massaverhoudings word aangegee.

Lantern-fish *Lampanyctodes hectoris* made their first documented appearance in South Africa's Western Cape purse-seine catches in 1966, shortly after the introduction of small-meshed (12,7 mm) nets, but the species was only recorded separately from anchovy *Engraulis capensis* during 1968 and subsequently (Crawford *et al.* 1978). Its contribution to the combined landings has been sporadic, a maximum of 42 369 metric tons being taken in 1973, but annual totals only exceeded 10 000 tons on two other occasions (Table I). This can probably be attributed to the preference of the species for deep water (Centurier-Harris 1974, Ahlstrom *et al.* 1976), making lantern-fish rarely available to purse-seiners. In addition, its high oil content has resulted in the clogging of machinery at fishmeal plants (Centurier-Harris *op. cit.*), and on such occasions factory managers often direct their skippers to search for other species.

Table I Annual catches of lantern-fish and percentage contribution to combined purse-seine landings, 1968—1976

Year	Catch (metric tons)	Percentage of combined purse-seine catch
1968	56	0,0
1969	4 945	1,4
1970	18 201	5,1
1971	2 047	0,6
1972	15 153	3,5
1973	42 369	9,4
1974	301	0,1
1975	87	0,0
1976	75	0,0

Off southern Africa, as elsewhere (Manzer 1968, Pereyra *et al.* 1969, Pinkas *et al.* 1971), the family Myctophidae forms an important component in the diet of many piscivorous fish. It comprises more than 75 per cent by weight of the food of young (caudal length 20⩽60 cm) hake *Merluccius* spp., is important in the diets of John Dory *Zeus capensis*, jacopever *Helicolenus maculatus* and angelfish *Brama raii* and is also eaten by large-scaled rattail *Coelorhynchus fasciatus*, smooth rattail *Lionurus nigromaculatus* and horse mackerel *Trachurus trachurus* (Davies 1949). Myctophids are ingested in large quantities by four tuna species, the southern bluefin *Thunnus maccoyii*, the longfin (albacore) *T. alalunga*, the yellowfin *T. albacares* and the bigeye *T. obesus* (De Jager *et al.* 1963, Nepgen 1970), are present in the stomachs of trawl-caught snoek *Thyrsites atun* (Nepgen 1979) and contribute 23 and 44 per cent of the food of medium (caudal length 26⩽45 cm) and large (caudal length ⩾46 cm) mackerel *Scomber japonicus* respectively (Baird 1978b).

The skins of lantern-fish are easily damaged and, for this reason, identification of specimens from stomachs is frequently difficult (Centurier-Harris 1974), especially when the stomach contents are well digested as is often the case (De Jager *et*

al. 1963). However, in view of the predominance of *L. hectoris* in the commercial purse-seine landings and also in an extensive plankton survey conducted off the coast of South West Africa between August 1972 and April 1974, when the species comprised more than 85 per cent of all myctophid larvae collected (Ahlstrom *et al.* 1976), it is thought likely that *L. hectoris* is the main contributor to the diet of the predatory fish mentioned earlier. The species is of particular interest because of the commercial importance of its predators, hake and mackerel, and on account of the interest in mid-water trawling for lantern-fish by certain fishing enterprises. This report therefore documents present knowledge of the distribution and availability (to purse-seine catchers) of *L. hectoris*. Certain basic information on length and mass relationships is also presented.

DISTRIBUTION OF COMMERCIAL CATCHES

Monthly distribution patterns of commercial catches for the period 1968 — 1976 were derived in a manner similar to that already described for pilchard *Sardinops ocellata* (Crawford 1979). The results are presented in chart form in the Appendix.

Examination of the length distributions of 31 purse-seine catches revealed that, in South African waters, lantern-fish from any one shoal seldom differ in caudal length by more than 3 or 4 cm (Fig. 1). The modal length of fish caught in known areas, whenever available from field observations, has therefore been included on the distribution charts to give some indication of the size of fish encountered.

As observed by Centurier-Harris (1974) and Centurier-Harris and Crawford (1974), the majority of catches have been made close to the mainland and in the region between the Olifants River and Dassen Island (see Appendix). Successful sets further north were made infrequently (January and February 1969, March 1971, January and February 1973 and February 1974) and to the east of Cape Point on only three occasions (March 1970, February 1972 and February 1973). In South African waters, the species has not been commercially exploited north of latitude 30°S or further east than Cape Agulhas, and the only truly offshore catch to have been reported was that to the south-west of Cape Point in February 1972.

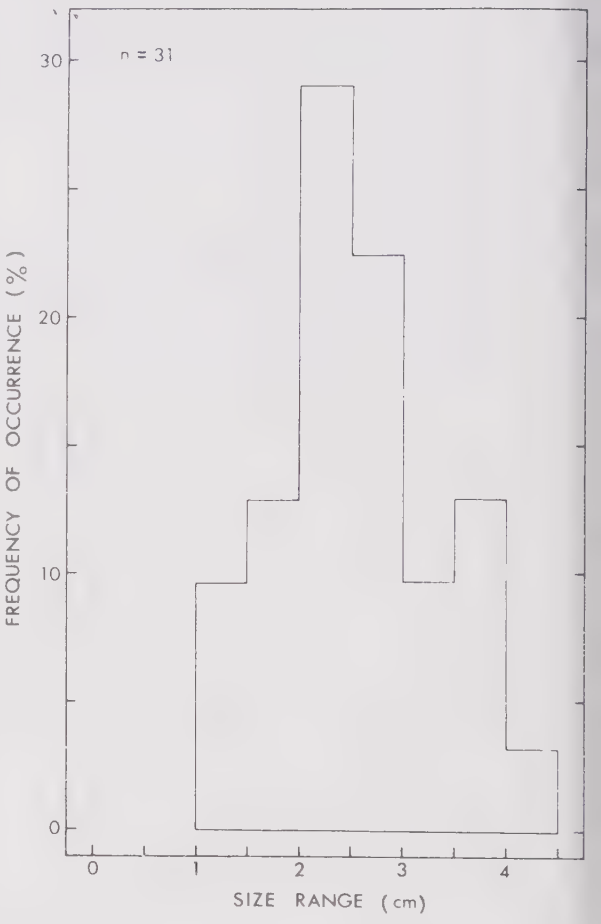

Fig. 1: Frequency of occurrence of variations in size-range between largest and smallest lantern-fish sampled from individual purse-seine catches

AVAILABILITY AND ABUNDANCE

Monthly indices of availability and of the relative abundance of lantern-fish that could, as a rule, be expected to be present on each of six fishing grounds (Fig. 2), chosen to correspond with the major environmental regions of the south-western Cape (Crawford *et al.* 1980), were determined in the same way as described for the pilchard population by Crawford (1979). A technique for ageing *L. hectoris* in South African waters has yet to be developed (Newman and Crawford, in press);

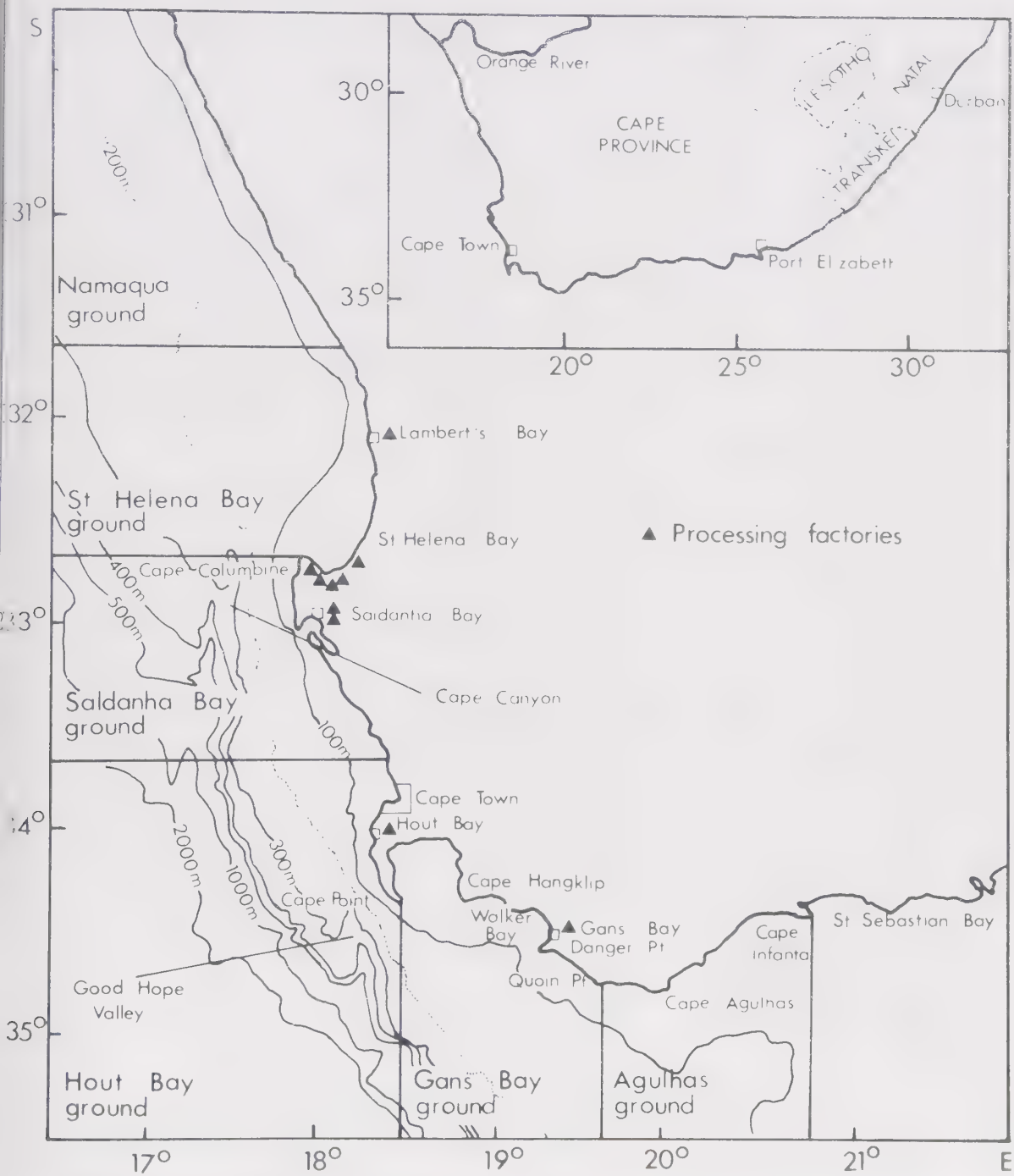

Fig. 2: The main South African purse-seine fishing grounds, showing the bottom topography and the locations of the processing factories operative in 1976 – the Namaqua ground extends north to the Orange River (inset)

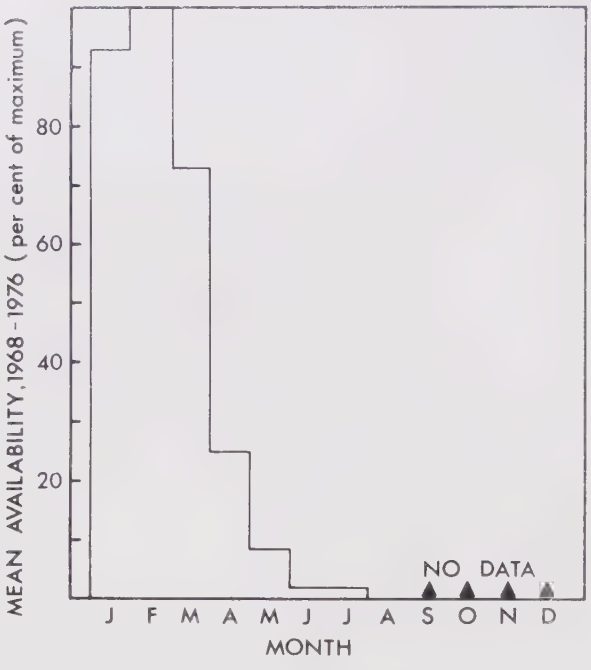

Fig. 3: Monthly availability indices for lantern-fish

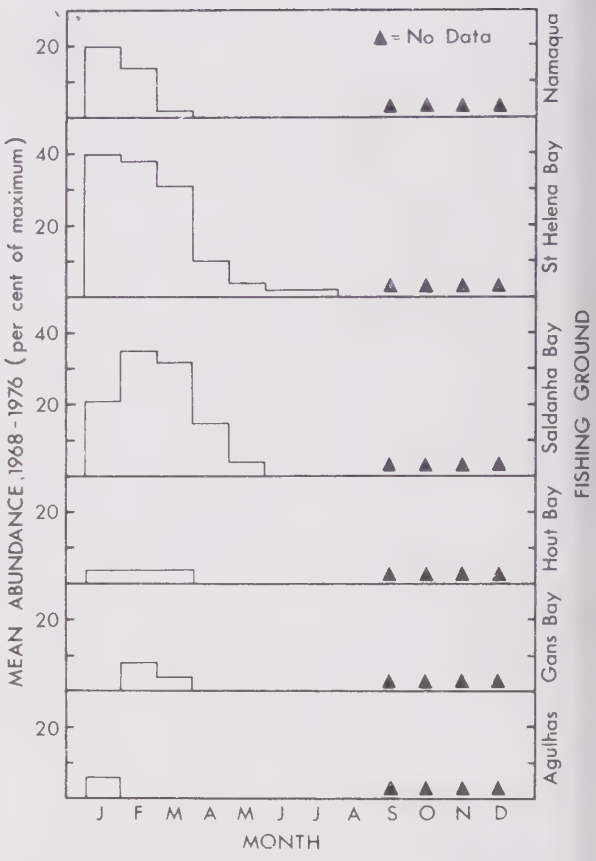

Fig. 4: Monthly abundance indices for lantern-fish for six fishing grounds

the population was therefore considered as an entity. Over the period 1968 to 1976, fishing for lantern-fish was not permitted between September and December, with the exception of September 1968. Therefore, values were not calculated for these months, but estimates for the remainder of the year, expressed as percentages of the maxima, appear in Figures 3 and 4.

Availability is high during January and February but declines rapidly thereafter (Fig. 3). An unrealistically high total mortality rate ($Z = 10{,}5$) would be required to account for the observed trend, which can therefore best be attributed to factors other than fishing. In contrast to estimates for the Namaqua and St Helena Bay grounds, the abundance index at Saldanha Bay (Fig. 4) increases from January to February, suggesting a slight southerly shift in distribution at this time. No subsequent movements can be discerned and the primary reason for the marked difference in availability between summer and winter remains, at this stage, uncertain. Its reality is emphasized by the fact that, whereas catch rates greater than 10 metric tons per standard-boat-day occurred fairly frequently during the first four months of the year (January 1969, 1971, 1972, 1973, 1976; February 1970, 1973; March 1970, 1972; April 1970, 1971) they were never recorded between May and August (see Appendix).

LENGTH AND MASS RELATIONSHIPS

The following formulae were derived for conversion of caudal length (L_c) to total length (L_t), both in centimetre, and for calculation of total fish mass (W) in gramme at any known size:

$$L_t = 1{,}1549\, L_c + 0{,}4724 \; (r = 0{,}99;\; P < 0{,}01;\; n = 800)$$

$$W = 0{,}0242\, L_c^{2.6838} (r = 0{,}96;\; P < 0{,}01;\; n = 800).$$

DISCUSSION

Analysis of sample information suggests that, even on those sporadic occasions when lantern-fish do become available to purse-seiners, the population is not fully represented. Commercial landings of lantern-fish are heavily dominated by females (Table II) and fish outside the L_C range 3,5 — 7,0 cm seldom occur (Fig. 5). Additionally, maturity studies of catches recorded between 1968 and 1976, following the classification of Davies (1956), revealed that gonads are virtually always either immature or inactive (Table III). The scarcity of males and the lack of mature ovaries are more understandable if it is borne in mind that the majority of the catches were made from January to April, i.e. outside the spawning season. Ahlstrom *et al.* (1976) reported that, off South West Africa, approximately 93 per cent of all *L. hectoris* larvae were taken between August and November, the early stages being most abundant in August.

Off Cape Columbine, the 200-m bottom contour approaches the mainland, and deep water is found close inshore (Fig. 2). It is in this area that the bulk of the lantern-fish catch is located. Purse-seine skippers generally prefer to remain within sight of the coast (Crawford 1979), and it is here in particular that they are most likely to encounter lantern-fish at the summit of the extensive vertical migrations the species is known to undertake (Centurier-

Table II: Sex ratio of lantern-fish occurring in commercial landings, 1968—1976

Year	Individuals with gonads too small to sex	Males	Females	Total
1968	40	—	50	90
1969	23	—	81	104
1970	—	—	250	250
1971	No sample information			
1972	No sample information			
1973	6	34	210	250
1974	No sample information			
1975	No sample information			
1976	19	—	25	44
1968 to 1976	88	34	616	738

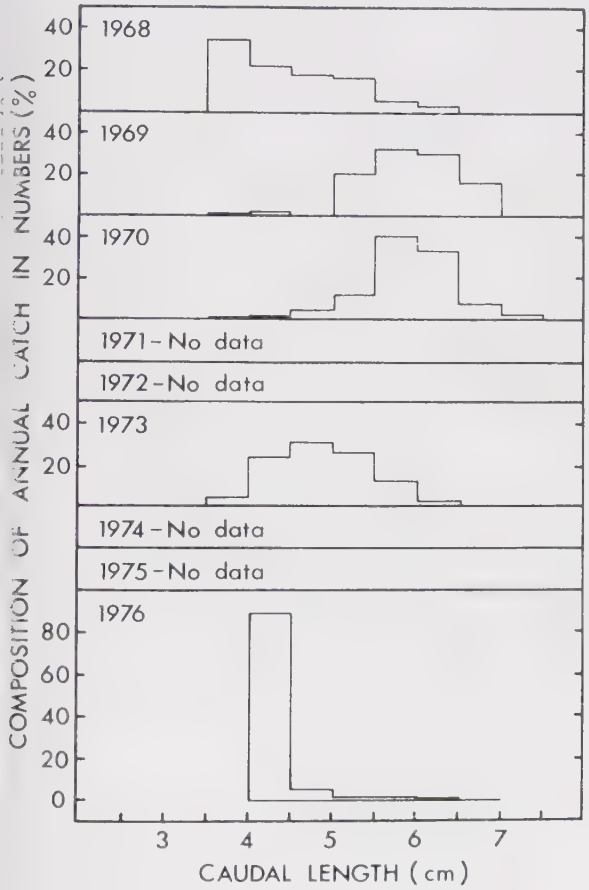

Fig. 5: Length distribution of South African lantern-fish landings, 1968—1976

Table III: Gonad maturity at length in lantern-fish, 1968—1976

Caudal length (cm)	Stage of maturity*				Total
	0	1	2	3	
3,0	—	2	—	—	2
3,5	—	16	—	—	16
4,0	—	76	—	—	76
4,5	—	124	—	2	126
5,0	2	136	—	—	138
5,5	2	171	—	1	174
6,0	23	109	—	—	132
6,5	23	42	—	—	65
7,0	1	7	—	—	8
Total	51	683	—	3	737

*Classification according to Davies (1956)

Harris 1974). A similar region exists south-west of Cape Point, but the fishing effort expended on these grounds is considerably less (Crawford *op. cit.*).

Bang and Andrews (1974) describe a pronounced sub-surface, north-flowing jet associated with and drawing its energy from a frontal feature situated some 40 miles west of Cape Town (Fig. 2). They postulate that its intensity may be a function of the local south-east wind stress and that, should this remain favourable for prolonged periods, the front would move seawards until reaching the edge of the continental shelf. The jet would then expand downwards.

The Cape Columbine vicinity is also characterized by powerful upwelling, especially when prevailing southerly to easterly winds blow. Plumes of cool, low-salinity water extend northwards and off shore, separated from oceanic waters by sharp gradients of temperature and salinity (Crawford *et al.* 1980). The physical oceanography is therefore similar to that of the Cape Town region. Strong, sub-surface currents have been measured in the Good Hope Valley and there is good reason to suppose that they occur in the Cape Canyon (G. Nelson, Sea Fisheries Institute, personal communication). The Cape Canyon comes to a head off Cape Columbine (Fig. 2) and a sub-surface current may be expected to be diverted upwards. This could have a marked bearing on the vertical positioning of lantern-fish in the water column, either directly or through influencing the location of food. The effect would be especially pronounced from late spring to early autumn when south-east winds are dominant, and it is at this time that lantern-fish are most available to purse-seiners (Fig. 3).

The Cape Columbine vicinity is also that in which adult mackerel migrate inshore to spawn during the winter months (Baird 1974). These mackerel often subsequently move in a southerly direction as far as Dassen Island, where they generally disappear (Baird 1978a). *L. hectoris* dominate their diet (Baird 1978b) and, although the availability of lantern-fish is minimal after April, adult mackerel have been netted while feeding on the species. Thus, the preference of mackerel aged three years and more for the northern fishing grounds (Crawford 1979), and for the Cape Columbine vicinity in particular, may well be correlated with the presence of lantern-fish.

A relatively diffuse distribution in the water column has been cited as one of the factors hampering commercial exploitation of lantern-fish species (Ahlstrom *et al.* 1976). Myctophids, however, have been known to form extensive aggregations in waters on the continental slope (Backus *et al.* 1968). In view of this and the evidence given previously, the Cape Columbine area would appear the obvious choice for exploratory mid-water fishing of *L. hectoris*, for either research or commercial purposes, and any attempts to estimate population size by acoustic or other surveys should be initiated in this region.

ACKNOWLEDGEMENTS

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APPENDIX

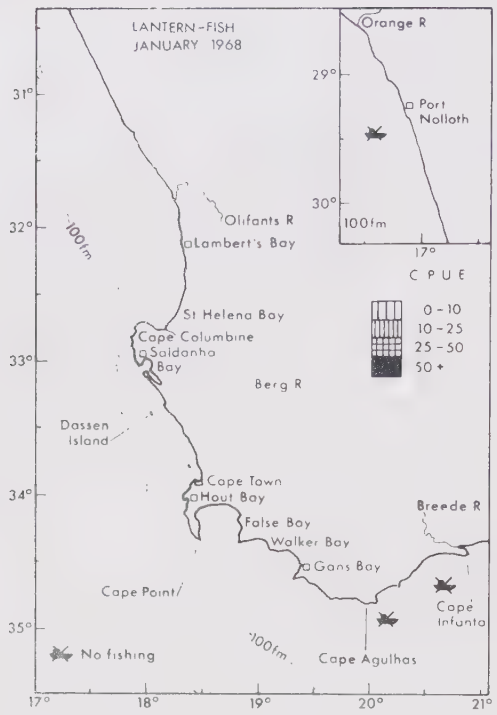
LANTERN-FISH CATCH LOCATIONS 1968–1976

From 1969 to 1976 no maps are shown for September–December inclusive, because exploitation of lantern-fish was prohibited during these months.

Levels of catch per unit effort (C.P.U.E.) are indicated as metric tons per standard-boat-day.

Modal caudal lengths (cm) of fish from different areas are shown adjacent to catch locations.

Areas in which there was no deployment of fishing effort are shown.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Saldanha Bay
Berg R
Dassen Island
Cape Town
Hout Bay
False Bay
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Breede R
Cape Point
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No fishing
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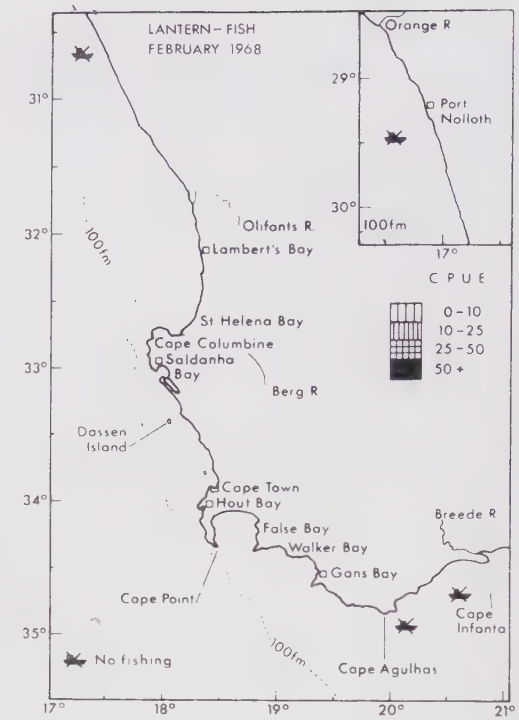
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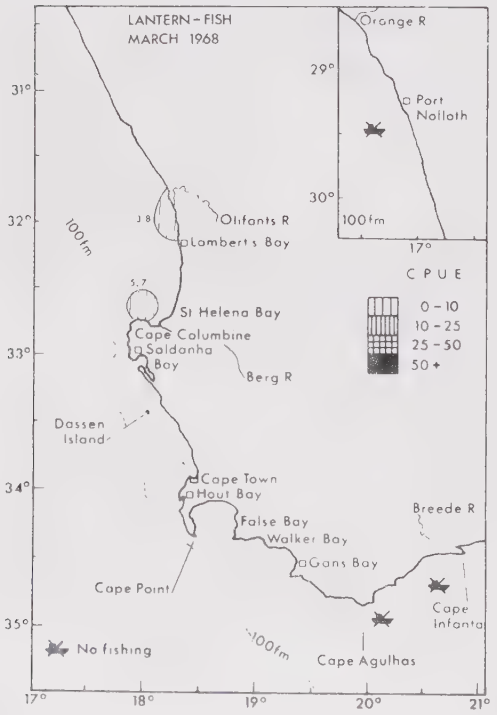
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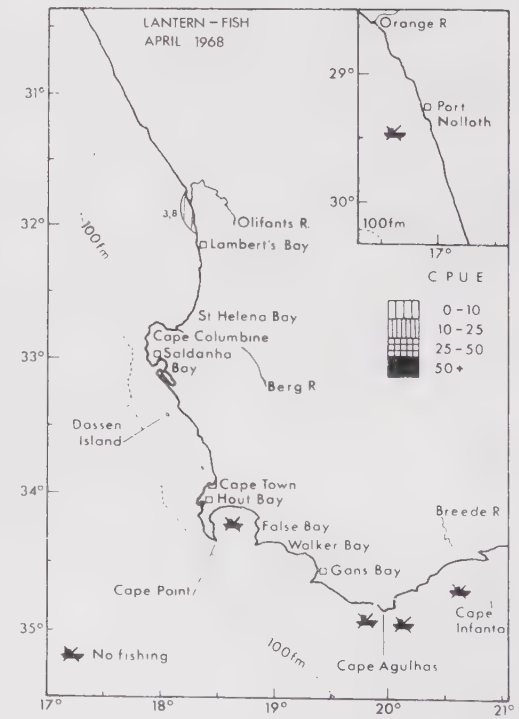
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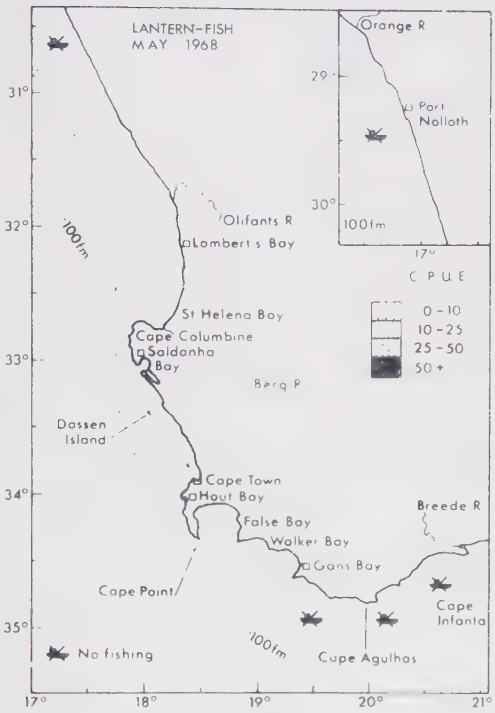
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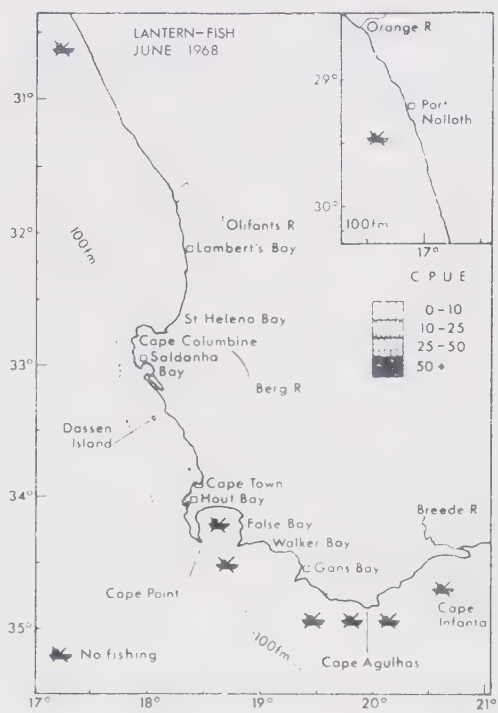
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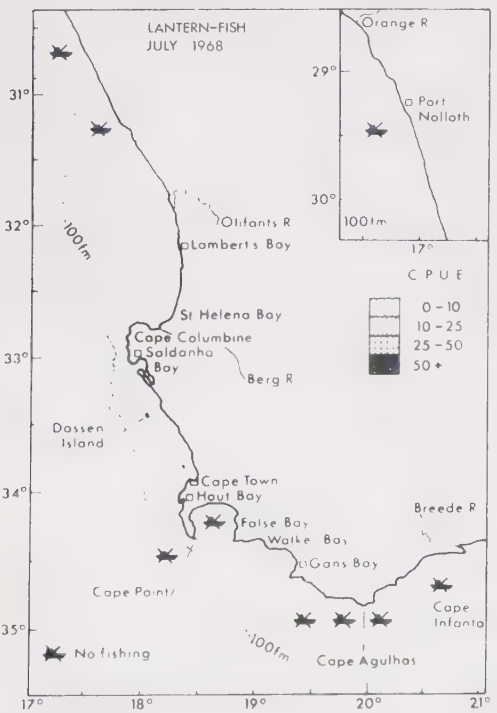
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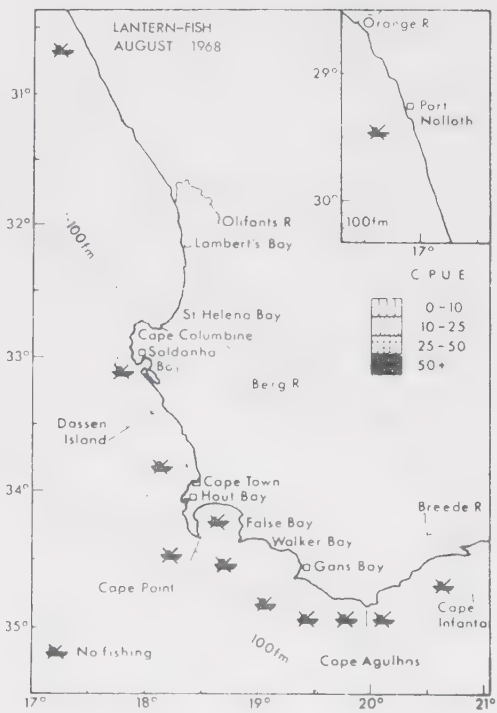
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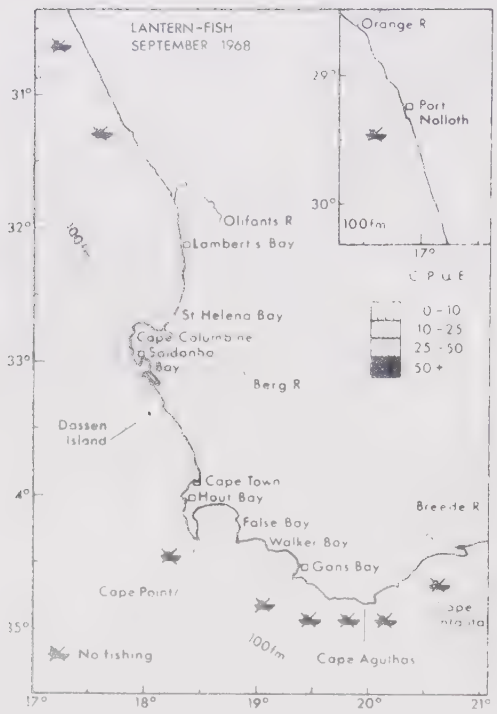
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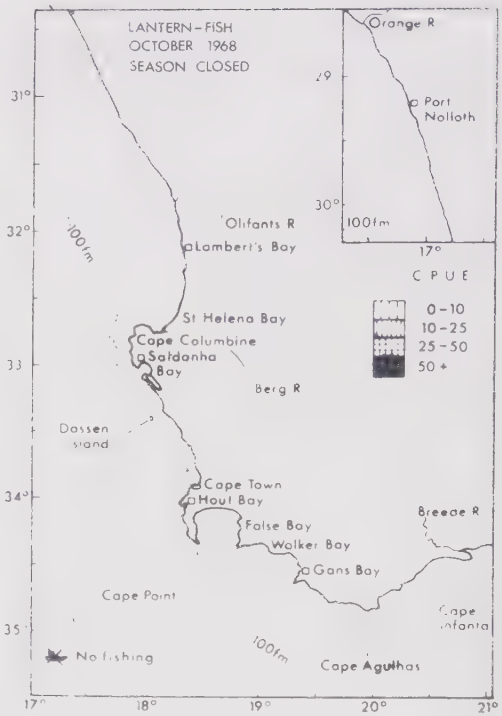
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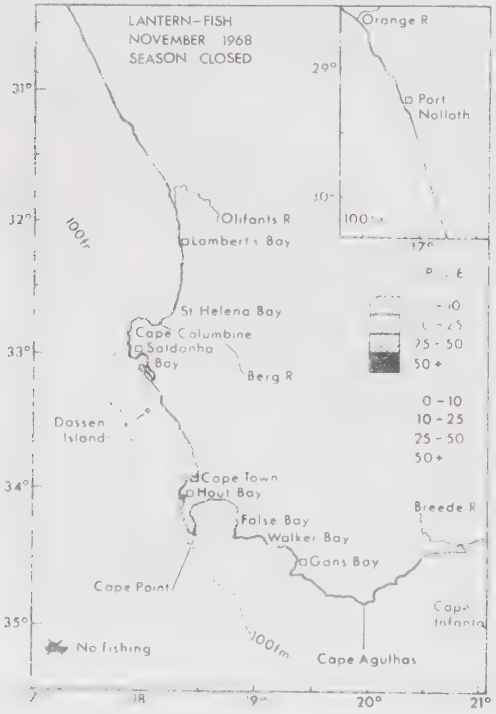
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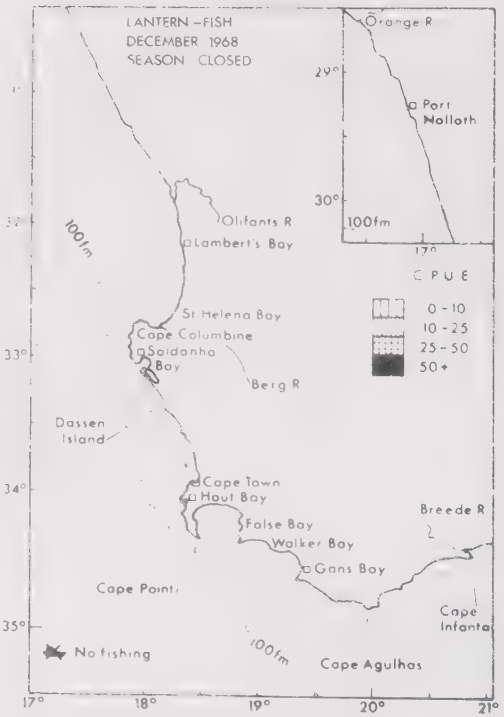
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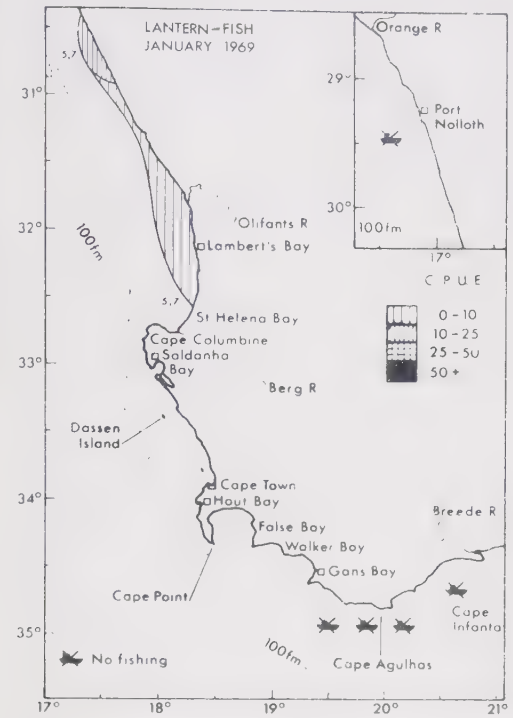
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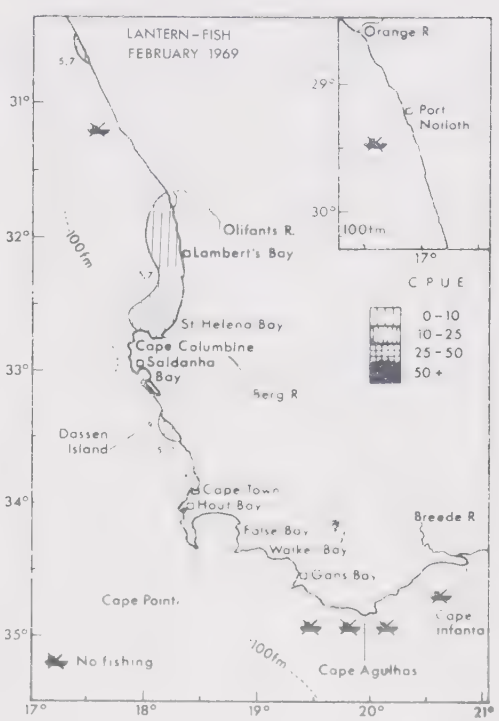
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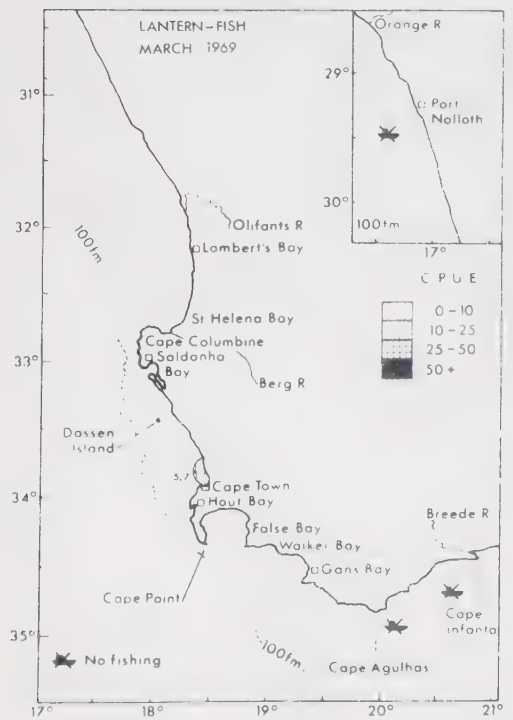
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St Helena Bay
Cape Columbine
Saldanha Bay
Berg R
Dassen Island
Cape Town
Hout Bay
False Bay
Walker Bay
Gans Bay
Breede R
Cape Point
Cape Infanta
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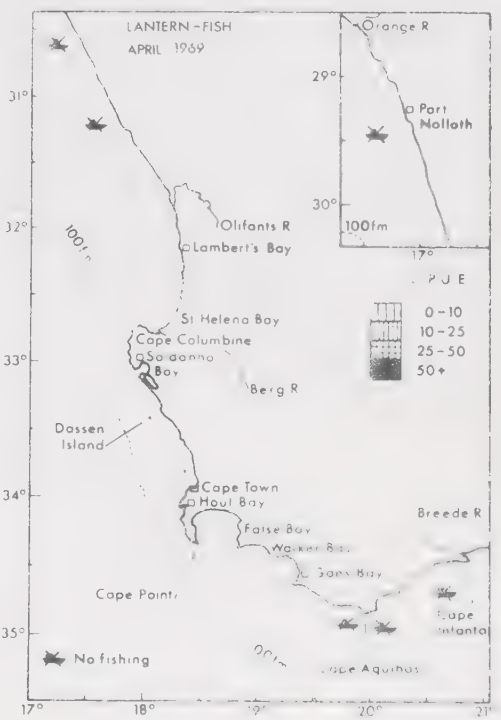
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Lambert's Bay
St Helena Bay
Cape Columbine
Berg R
Dassen Island
Cape Town
Hout Bay
False Bay
Gans Bay
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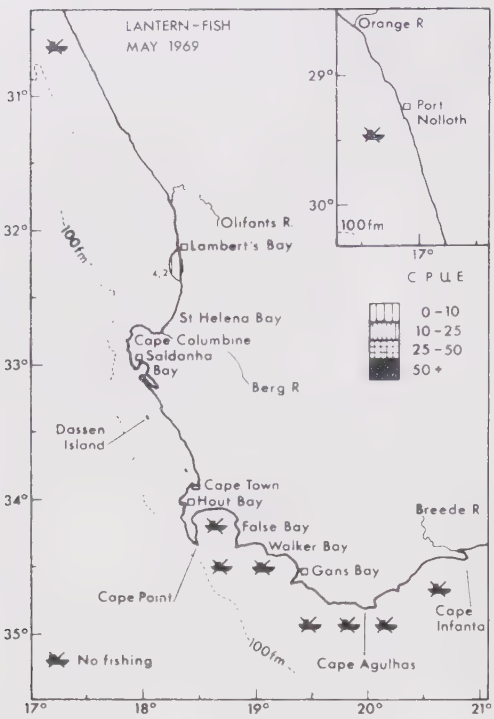
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St Helena Bay
Cape Columbine
Saldanha Bay
Berg R
Dassen Island
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Breede R
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Cape Infanta
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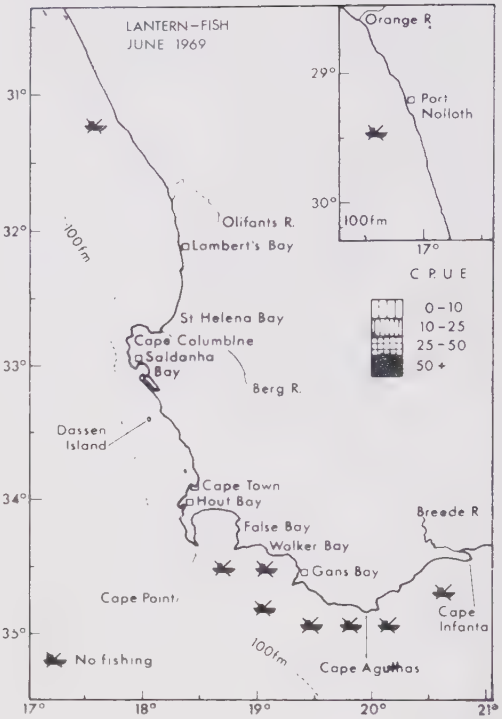
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Lambert's Bay
St Helena Bay
Cape Columbine
Saldanha Bay
Berg R.
Dassen Island
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Breede R
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Cape Infanta
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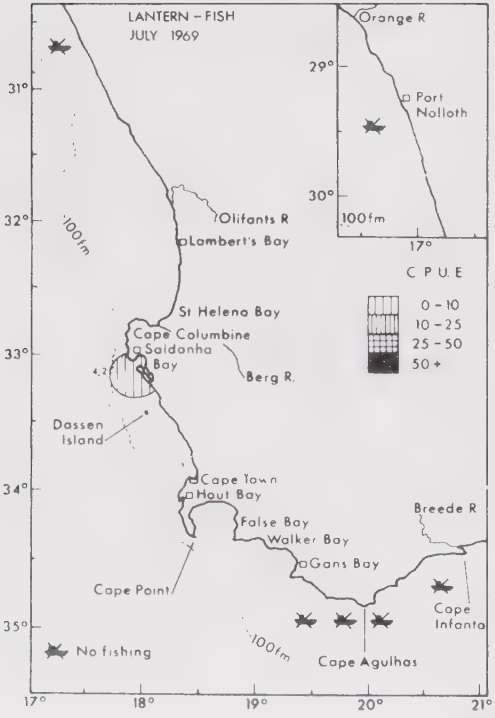
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St Helena Bay
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Berg R.
Dassen Island
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Cape Infanta
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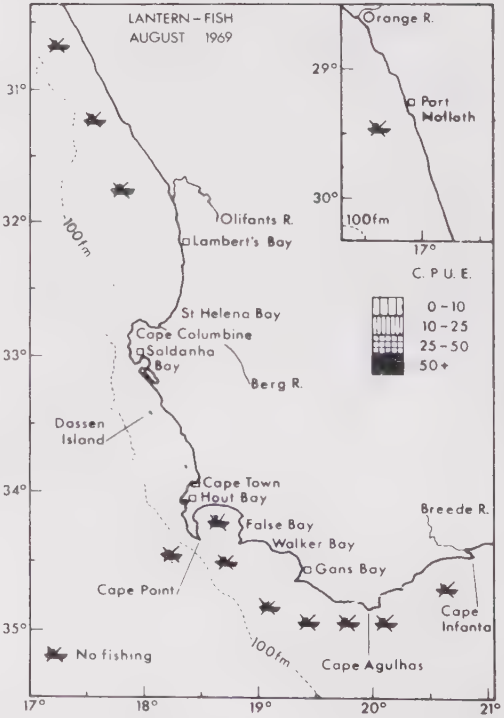
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Lambert's Bay
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Dassen Island
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Breede R.
Cape Point
Cape Infanta
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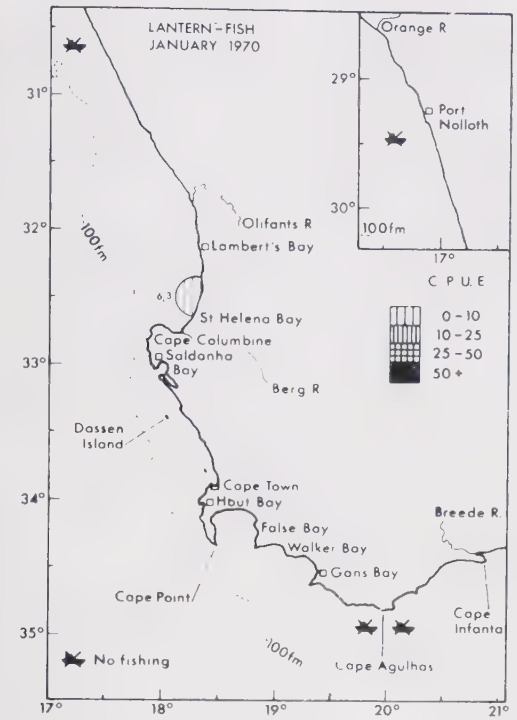
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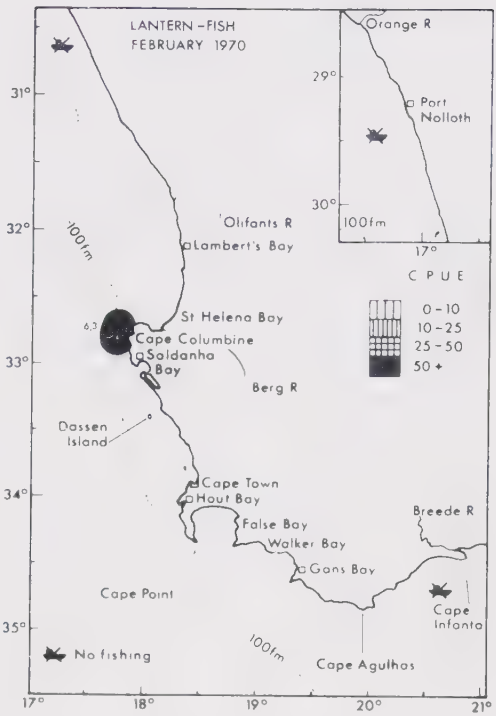
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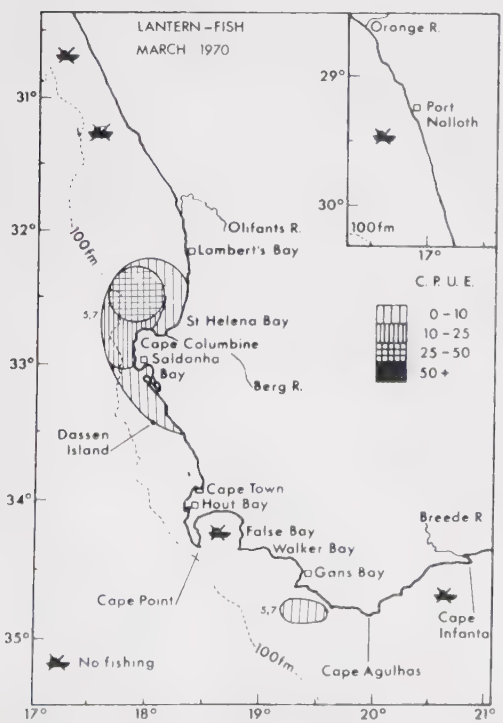
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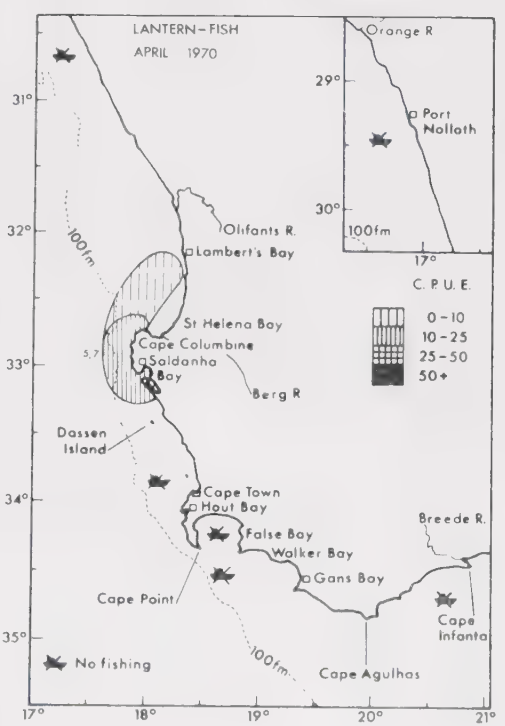
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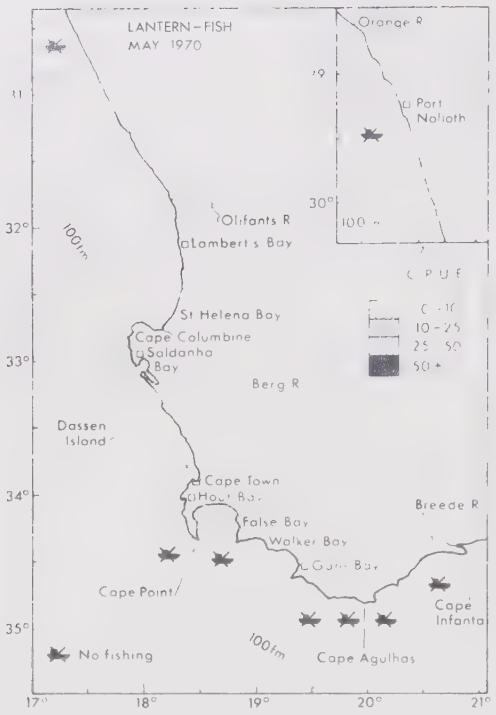
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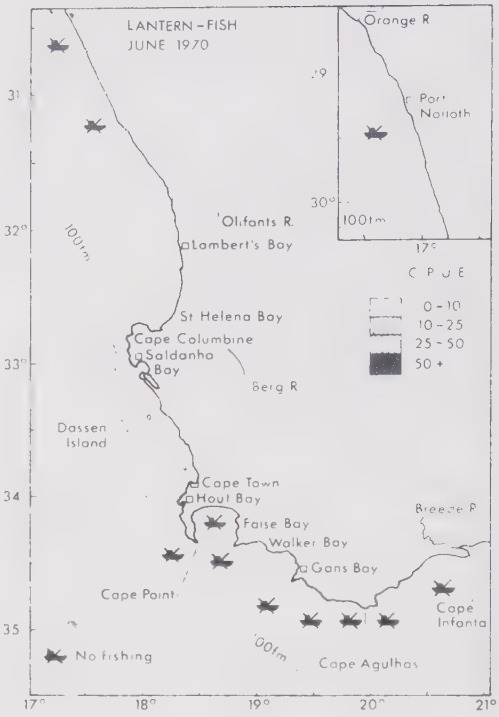
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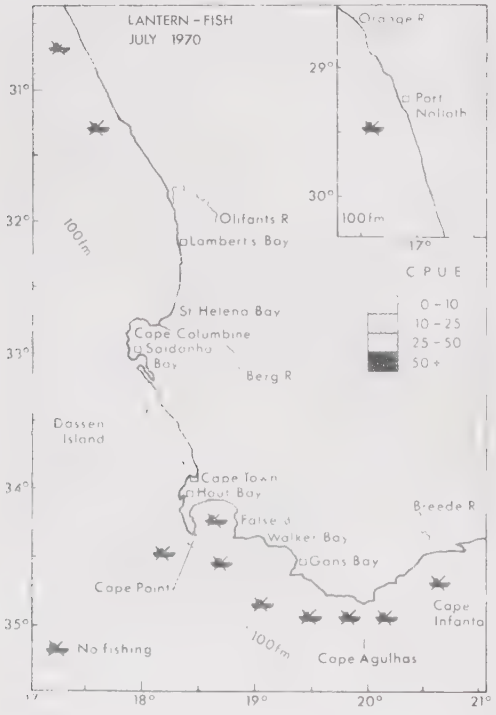
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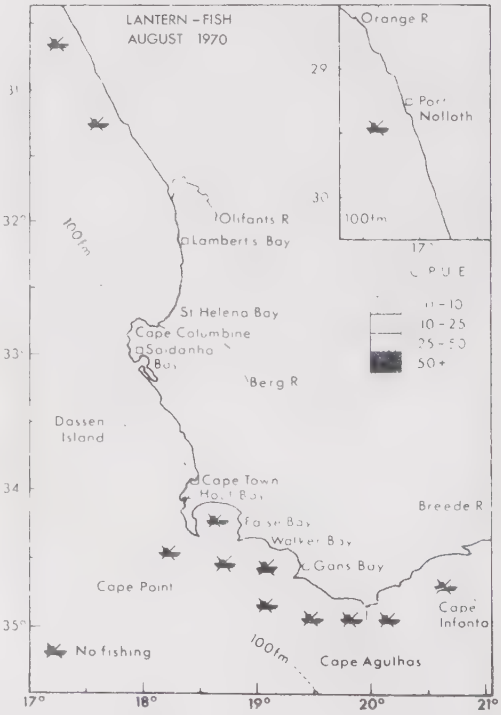
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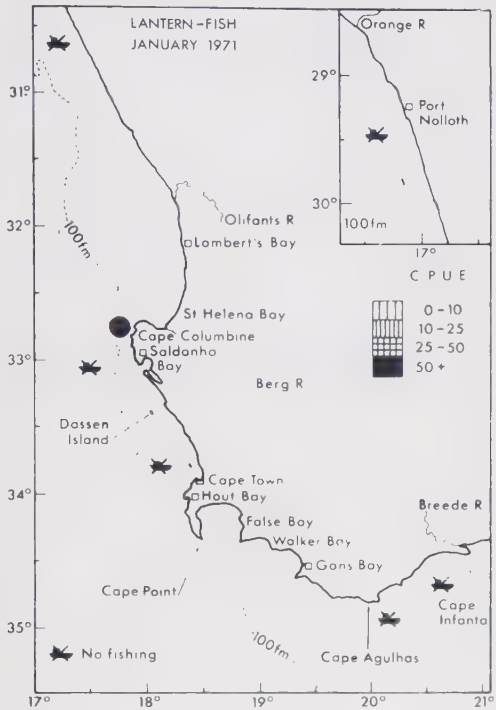
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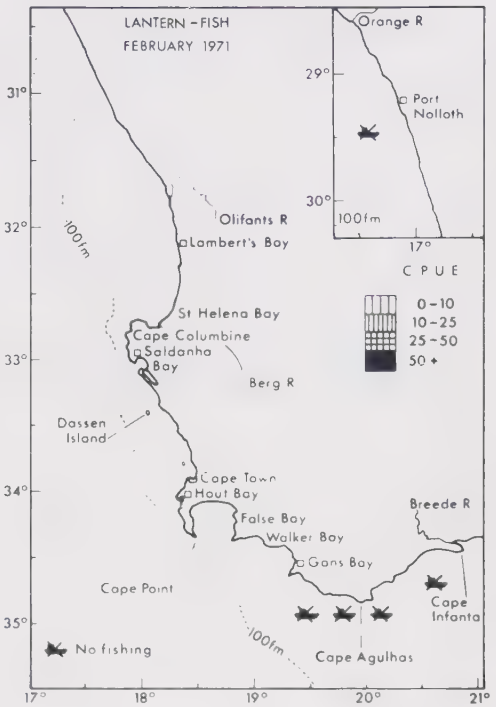
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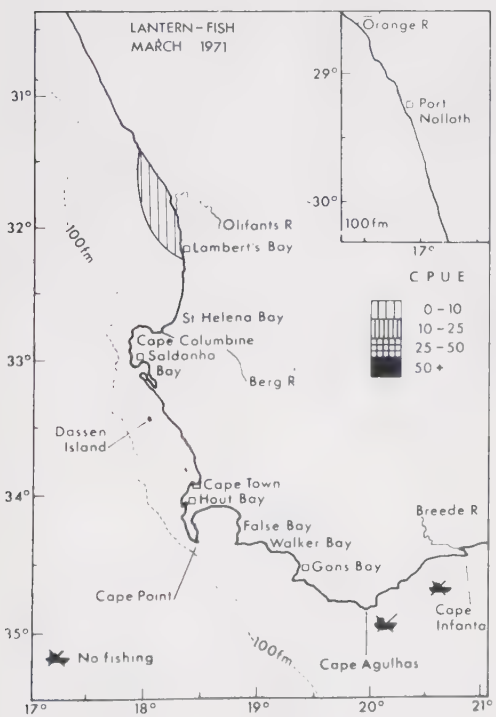
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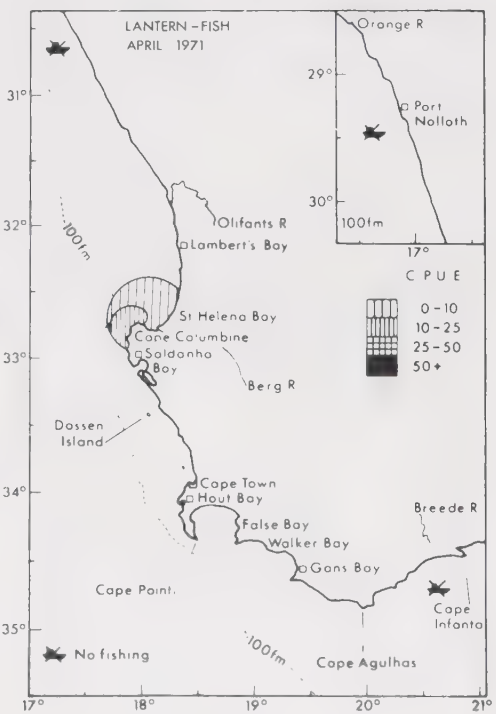
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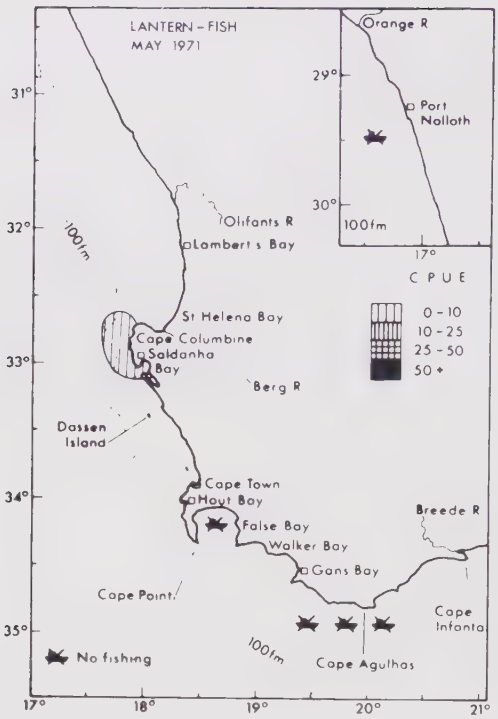
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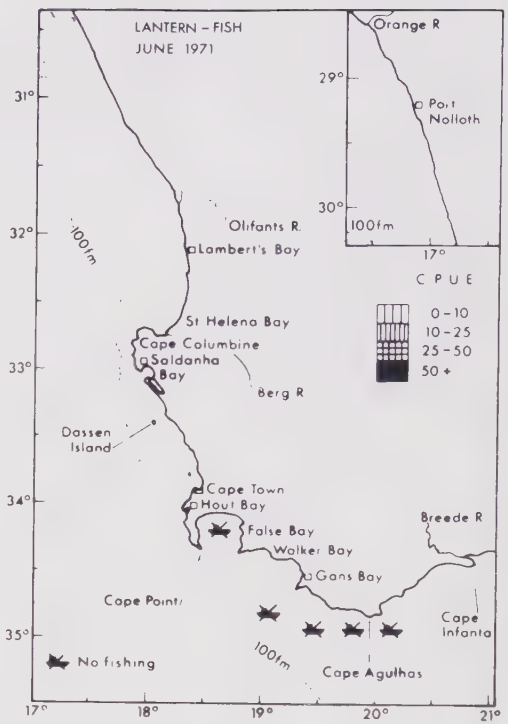
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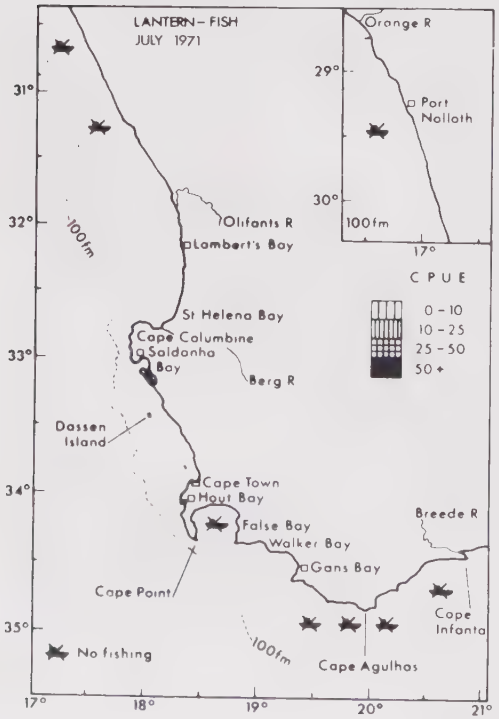
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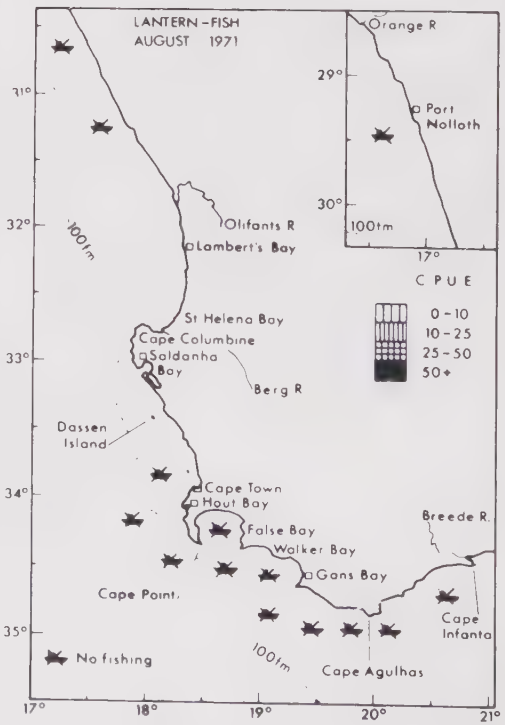
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AUGUST 1971
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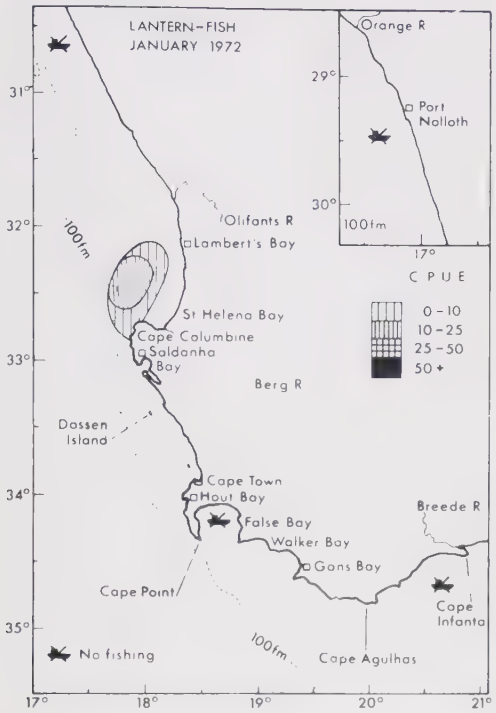
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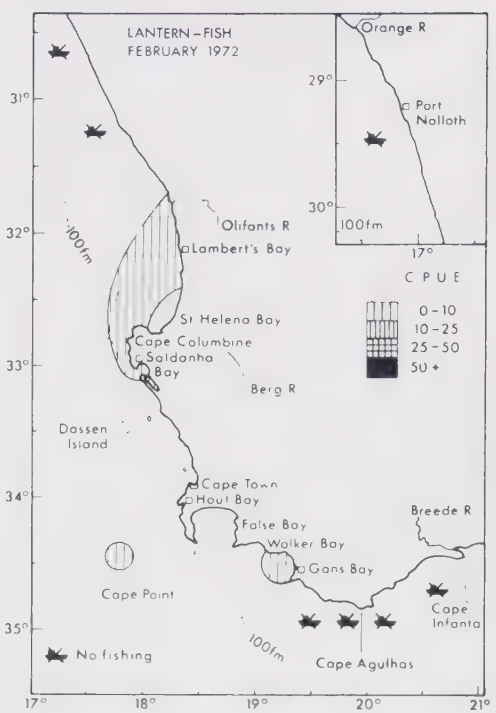
LANTERN-FISH
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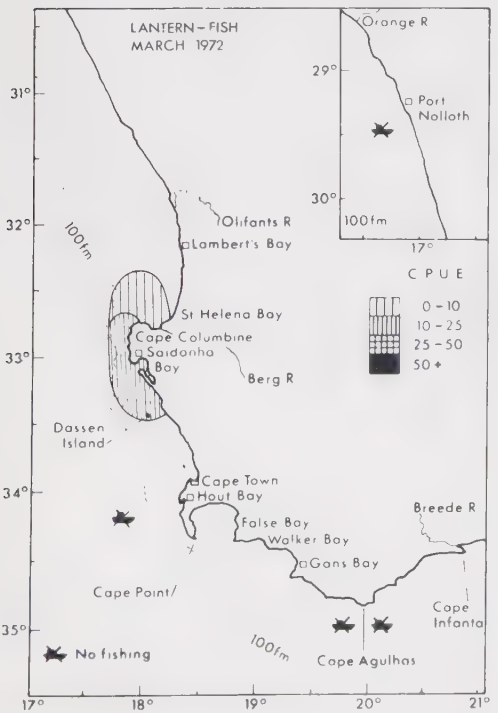
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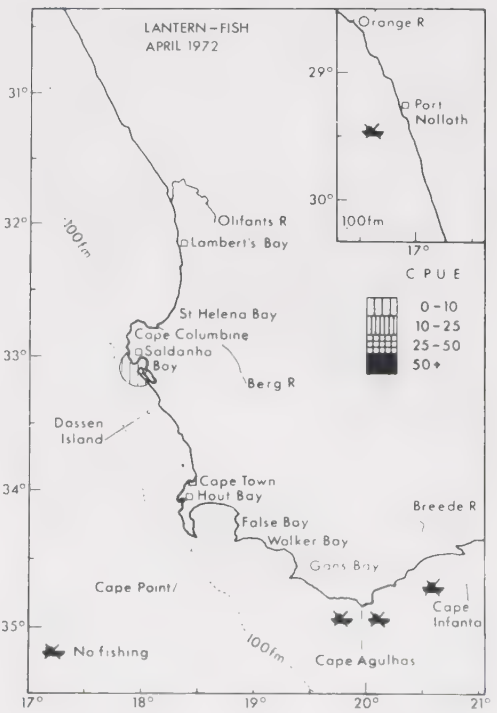
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Berg R
Dassen Island
Cape Town
Hout Bay
False Bay
Walker Bay
Gans Bay
Breede R
Cape Point
Cape Infanta
Cape Agulhas
No fishing
31°
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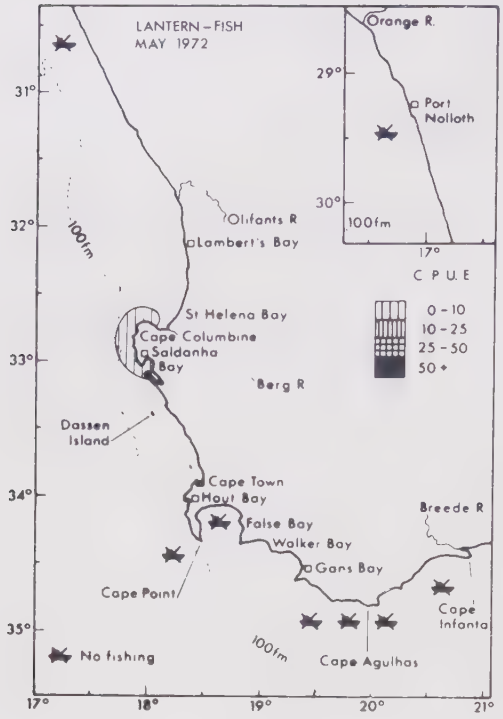
LANTERN – FISH
MAY 1972
Orange R.
Port Nolloth
100fm
C P U E
0 – 10
10 – 25
25 – 50
50 +
Olifants R.
Lambert's Bay
St Helena Bay
Cape Columbine
Saldanha Bay
Berg R.
Dassen Island
Cape Town
Hout Bay
False Bay
Walker Bay
Gans Bay
Breede R.
Cape Point
Cape Infanta
Cape Agulhas
No fishing
31°
32°
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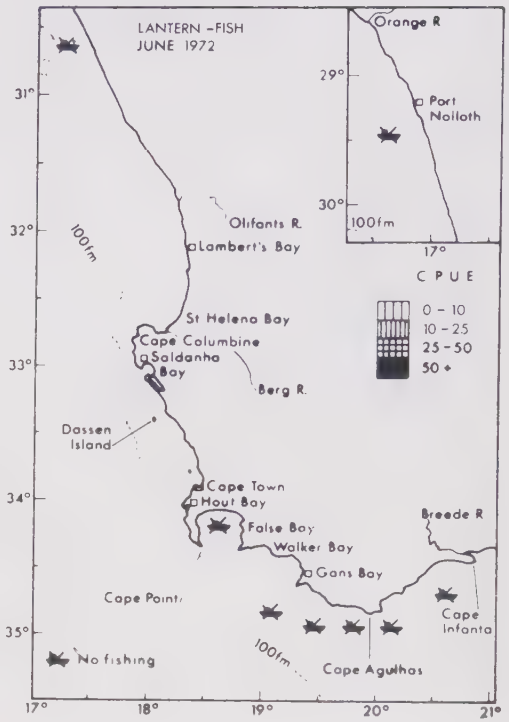
LANTERN – FISH
JUNE 1972
Orange R
Port Nolloth
100fm
C P U E
0 – 10
10 – 25
25 – 50
50 +
Olifants R.
Lambert's Bay
St Helena Bay
Cape Columbine
Saldanha Bay
Berg R.
Dassen Island
Cape Town
Hout Bay
False Bay
Walker Bay
Gans Bay
Breede R
Cape Point
Cape Infanta
Cape Agulhas
No fishing
31°
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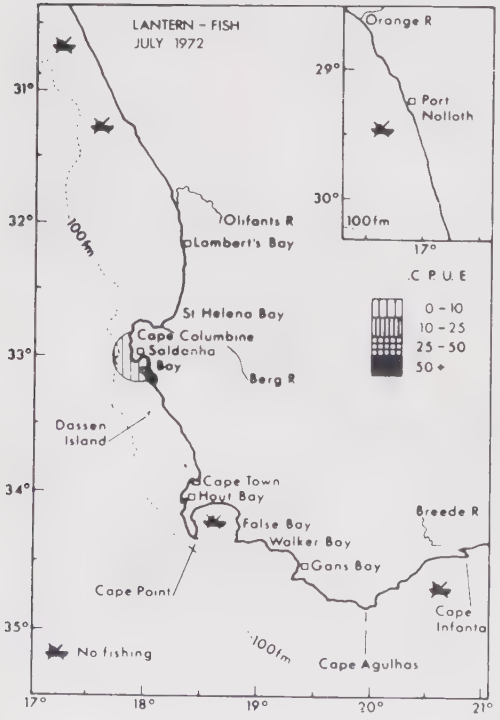
LANTERN – FISH
JULY 1972
Orange R
Port Nolloth
100fm
C P U E
0 – 10
10 – 25
25 – 50
50 +
Olifants R
Lambert's Bay
St Helena Bay
Cape Columbine
Saldanha Bay
Berg R
Dassen Island
Cape Town
Hout Bay
False Bay
Walker Bay
Gans Bay
Breede R
Cape Point
Cape Infanta
Cape Agulhas
No fishing
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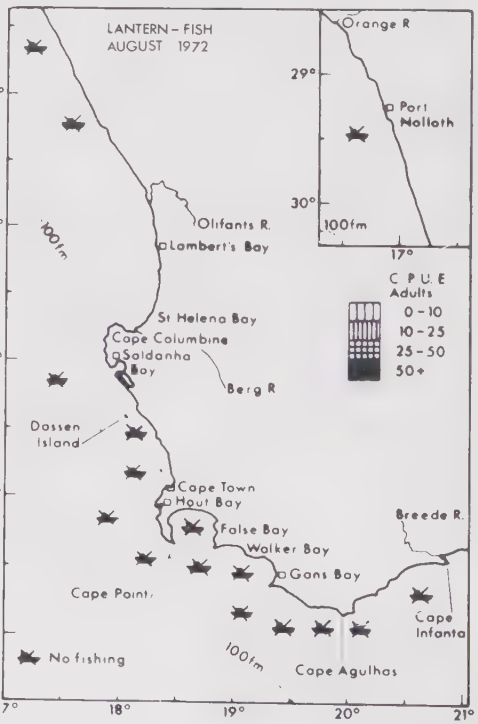
LANTERN – FISH
AUGUST 1972
Orange R
Port Nolloth
100fm
C P U E
Adults
0 – 10
10 – 25
25 – 50
50 +
Olifants R.
Lambert's Bay
St Helena Bay
Cape Columbine
Saldanha Bay
Berg R
Dassen Island
Cape Town
Hout Bay
False Bay
Walker Bay
Gans Bay
Breede R.
Cape Point
Cape Infanta
Cape Agulhas
No fishing
31°
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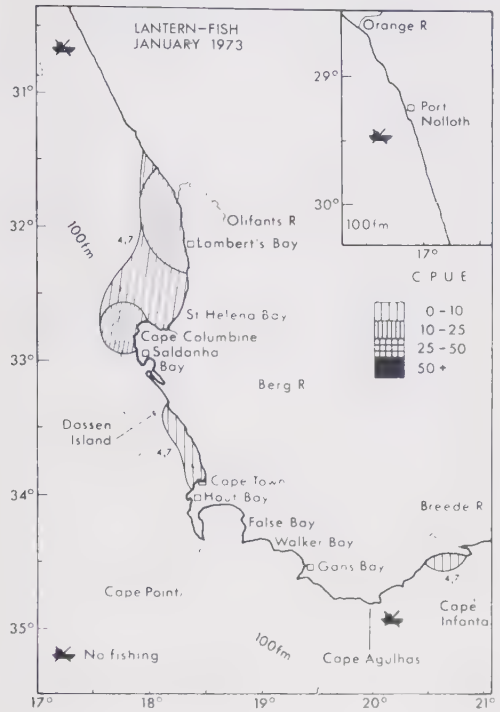
LANTERN–FISH
JANUARY 1973
Orange R
Port Nolloth
100fm
Olifants R
Lambert's Bay
St Helena Bay
Cape Columbine
Saldanha Bay
Berg R
Dassen Island
Cape Town
Hout Bay
False Bay
Walker Bay
Gans Bay
Breede R
Cape Point
Cape Infanta
Cape Agulhas
No fishing
CPUE
0 – 10
10 – 25
25 – 50
50 +
4,7
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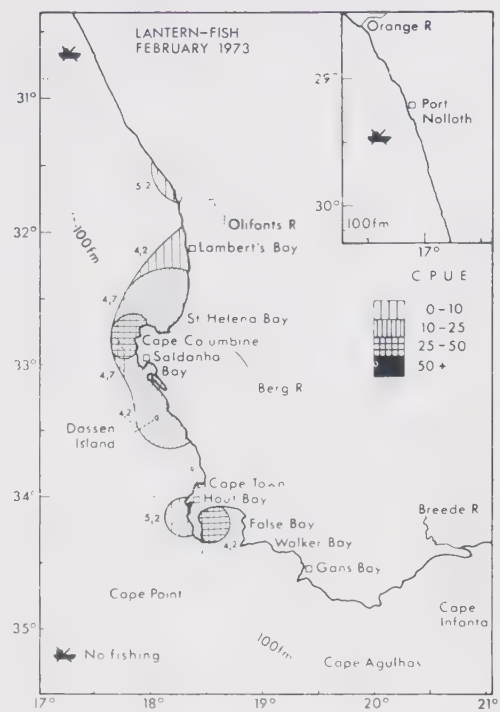
LANTERN–FISH
FEBRUARY 1973
Orange R
Port Nolloth
100fm
Olifants R
Lambert's Bay
St Helena Bay
Cape Columbine
Saldanha Bay
Berg R
Dassen Island
Cape Town
Hout Bay
False Bay
Walker Bay
Gans Bay
Breede R
Cape Point
Cape Infanta
Cape Agulhas
No fishing
CPUE
0 – 10
10 – 25
25 – 50
50 +
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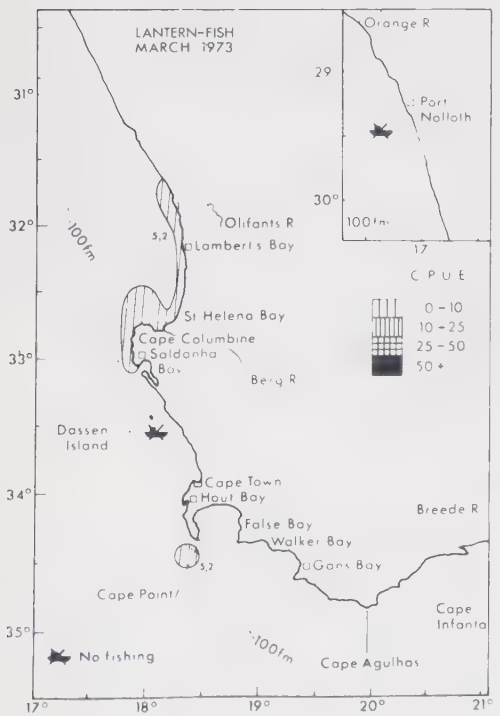
LANTERN–FISH
MARCH 1973
Orange R
Port Nolloth
100fm
Olifants R
Lambert's Bay
St Helena Bay
Cape Columbine
Saldanha Bay
Berg R
Dassen Island
Cape Town
Hout Bay
False Bay
Walker Bay
Gans Bay
Breede R
Cape Point
Cape Infanta
Cape Agulhas
No fishing
CPUE
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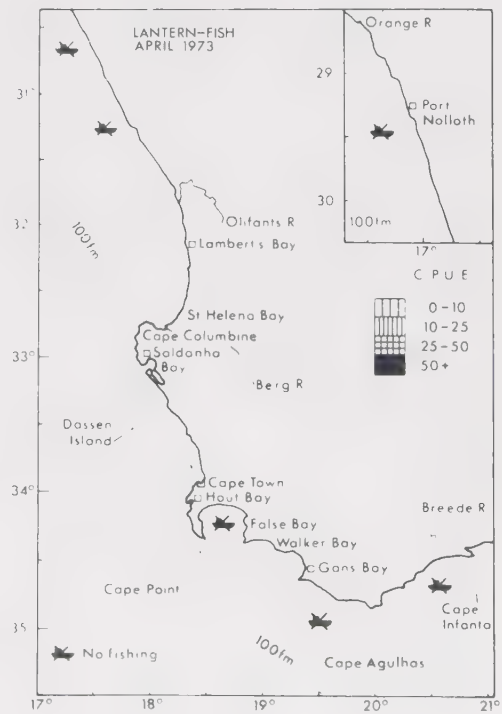
LANTERN–FISH
APRIL 1973
Orange R
Port Nolloth
100fm
Olifants R
Lambert's Bay
St Helena Bay
Cape Columbine
Saldanha Bay
Berg R
Dassen Island
Cape Town
Hout Bay
False Bay
Walker Bay
Gans Bay
Breede R
Cape Point
Cape Infanta
Cape Agulhas
No fishing
CPUE
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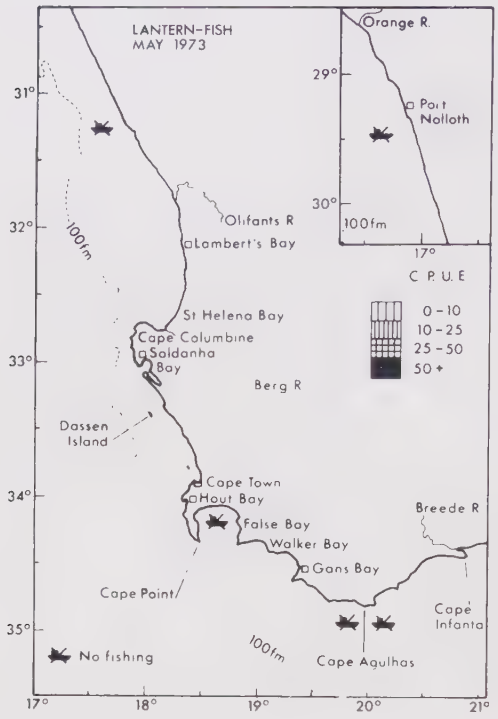
LANTERN-FISH
MAY 1973
Orange R.
Port Nolloth
100fm
C P U E
0 - 10
10 - 25
25 - 50
50 +
Olifants R
Lambert's Bay
St Helena Bay
Cape Columbine
Saldanha Bay
Berg R
Dassen Island
Cape Town
Hout Bay
False Bay
Walker Bay
Gans Bay
Breede R
Cape Point
Cape Infanta
Cape Agulhas
No fishing
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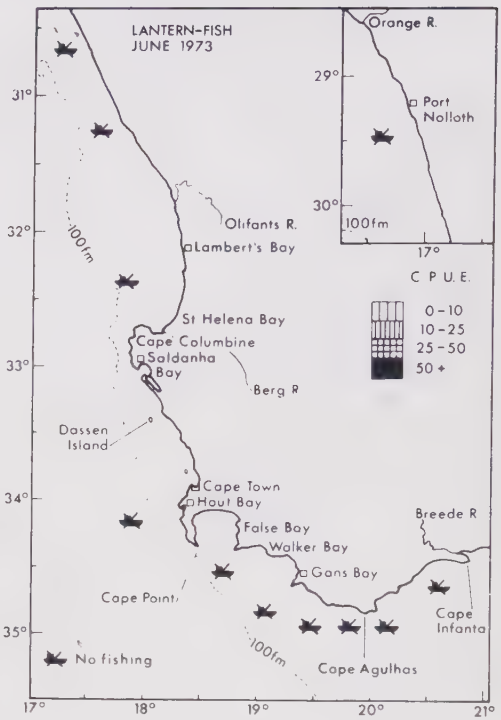
LANTERN-FISH
JUNE 1973
Orange R.
Port Nolloth
100fm
C P U E.
0 - 10
10 - 25
25 - 50
50 +
Olifants R.
Lambert's Bay
St Helena Bay
Cape Columbine
Saldanha Bay
Berg R
Dassen Island
Cape Town
Hout Bay
False Bay
Walker Bay
Gans Bay
Breede R
Cape Point
Cape Infanta
Cape Agulhas
No fishing
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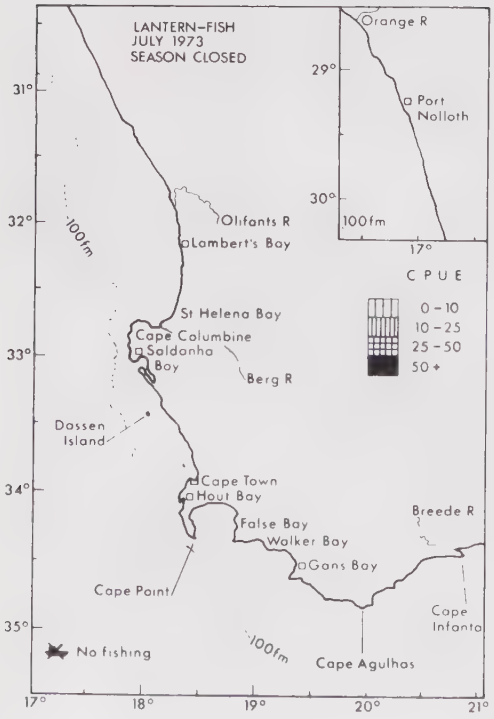
LANTERN-FISH
JULY 1973
SEASON CLOSED
Orange R
Port Nolloth
100fm
C P U E
0 - 10
10 - 25
25 - 50
50 +
Olifants R
Lambert's Bay
St Helena Bay
Cape Columbine
Saldanha Bay
Berg R
Dassen Island
Cape Town
Hout Bay
False Bay
Walker Bay
Gans Bay
Breede R
Cape Point
Cape Infanta
Cape Agulhas
No fishing
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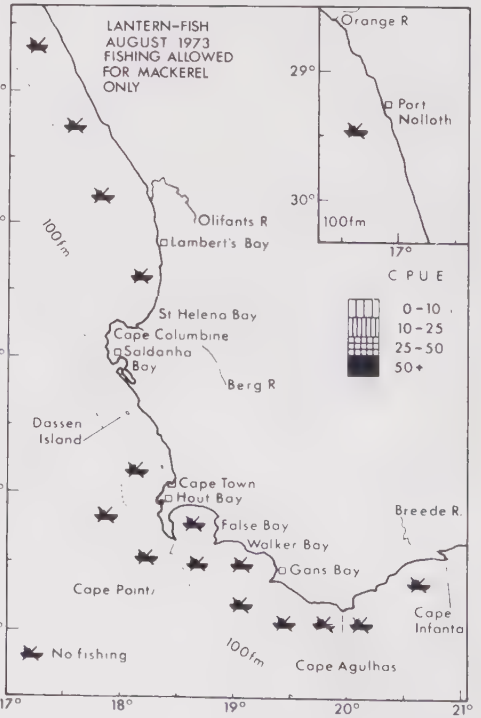
LANTERN-FISH
AUGUST 1973
FISHING ALLOWED
FOR MACKEREL
ONLY
Orange R
Port Nolloth
100fm
C P U E
0 - 10
10 - 25
25 - 50
50 +
Olifants R
Lambert's Bay
St Helena Bay
Cape Columbine
Saldanha Bay
Berg R
Dassen Island
Cape Town
Hout Bay
False Bay
Walker Bay
Gans Bay
Breede R.
Cape Point
Cape Infanta
Cape Agulhas
No fishing
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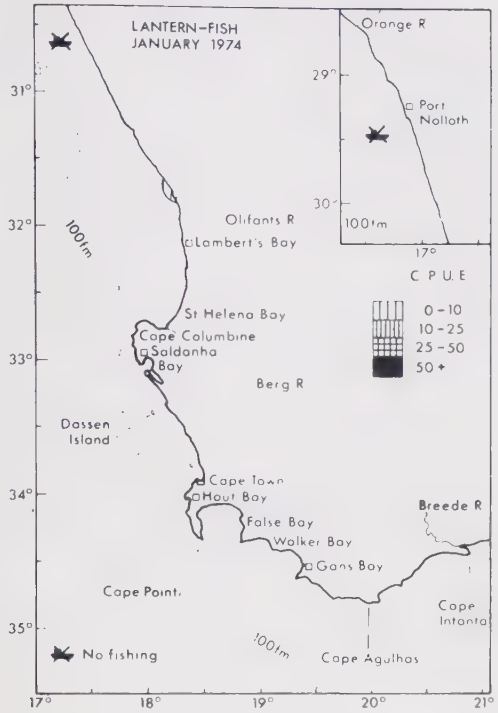
LANTERN-FISH
JANUARY 1974
Orange R
Port Nolloth
29°
30°
100fm
17°
C P U E
0 - 10
10 - 25
25 - 50
50 +
Olifants R
Lambert's Bay
St Helena Bay
Cape Columbine
Saldanha Bay
Berg R
Dassen Island
Cape Town
Hout Bay
False Bay
Walker Bay
Gans Bay
Breede R
Cape Point
Cape Infanta
Cape Agulhas
No fishing
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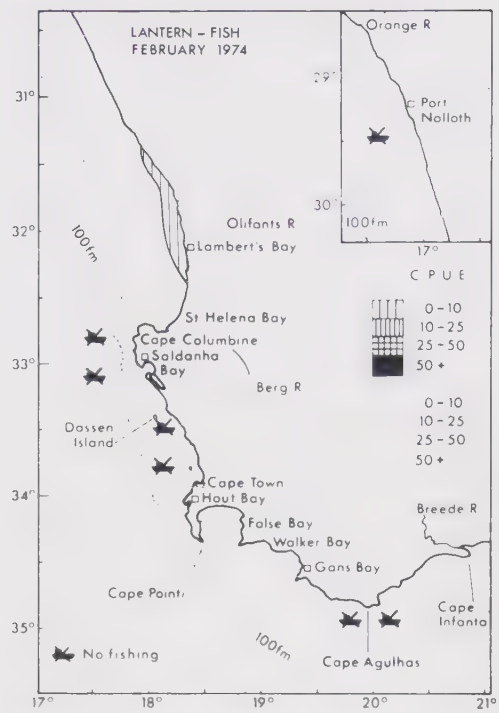
LANTERN - FISH
FEBRUARY 1974
Orange R
Port Nolloth
29°
30°
100fm
17°
C P U E
0 - 10
10 - 25
25 - 50
50 +
Olifants R
Lambert's Bay
St Helena Bay
Cape Columbine
Saldanha Bay
Berg R
Dassen Island
Cape Town
Hout Bay
False Bay
Walker Bay
Gans Bay
Breede R
Cape Point
Cape Infanta
Cape Agulhas
No fishing
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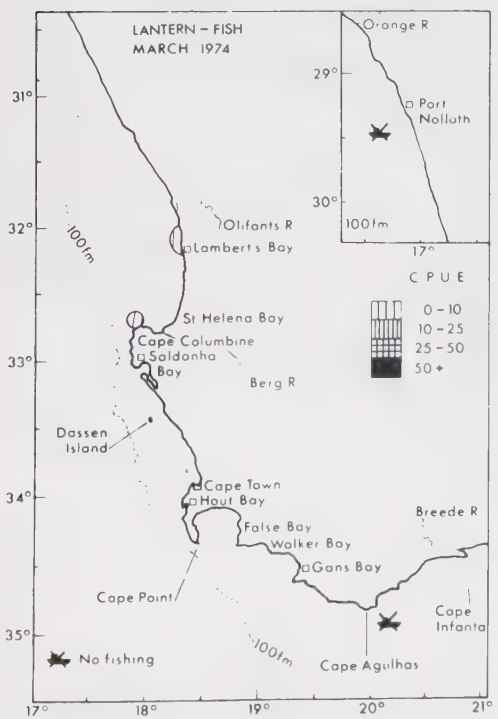
LANTERN - FISH
MARCH 1974
Orange R
Port Nolloth
29°
30°
100fm
17°
C P U E
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10 - 25
25 - 50
50 +
Olifants R
Lambert's Bay
St Helena Bay
Cape Columbine
Saldanha Bay
Berg R
Dassen Island
Cape Town
Hout Bay
False Bay
Walker Bay
Gans Bay
Breede R
Cape Point
Cape Infanta
Cape Agulhas
No fishing
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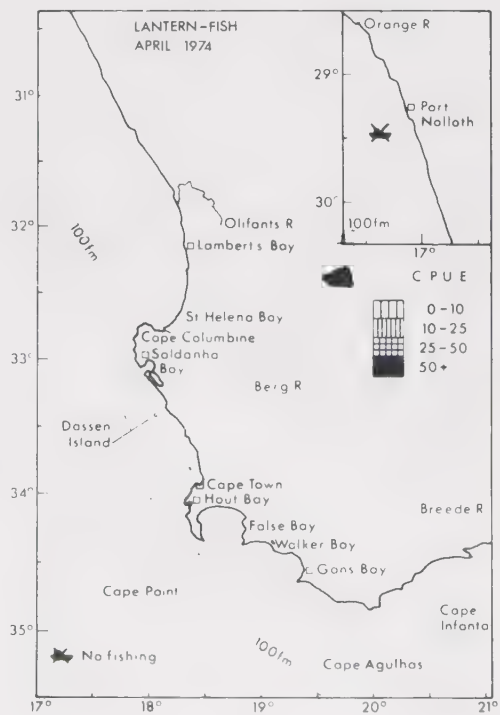
LANTERN-FISH
APRIL 1974
Orange R
Port Nolloth
29°
30°
100fm
17°
C P U E
0 - 10
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50 +
Olifants R
Lambert's Bay
St Helena Bay
Cape Columbine
Saldanha Bay
Berg R
Dassen Island
Cape Town
Hout Bay
False Bay
Walker Bay
Gans Bay
Breede R
Cape Point
Cape Infanta
Cape Agulhas
No fishing
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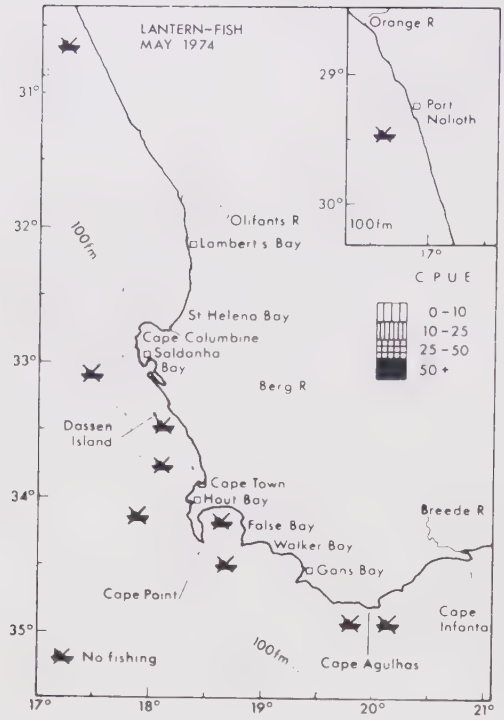
LANTERN-FISH
MAY 1974
Orange R
Port Nolloth
100fm
CPUE
0-10
10-25
25-50
50+
Olifants R
Lambert's Bay
St Helena Bay
Cape Columbine
Saldanha Bay
Berg R
Dassen Island
Cape Town
Hout Bay
False Bay
Walker Bay
Gans Bay
Breede R
Cape Point
Cape Infanta
Cape Agulhas
No fishing
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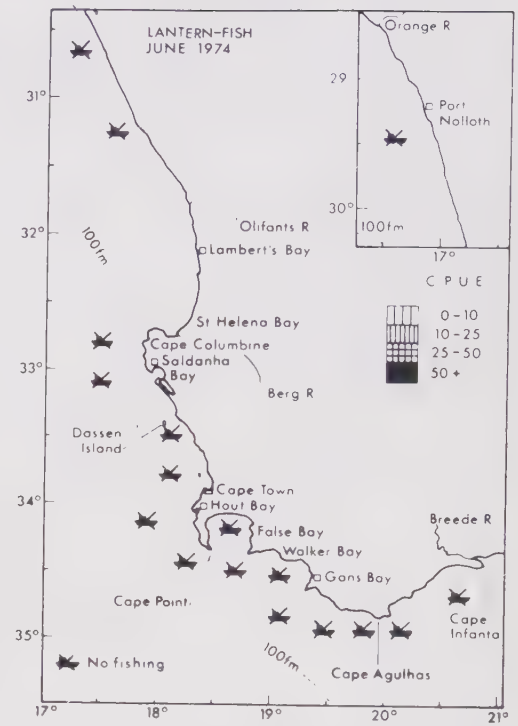
LANTERN-FISH
JUNE 1974
Orange R
Port Nolloth
100fm
CPUE
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25-50
50+
Olifants R
Lambert's Bay
St Helena Bay
Cape Columbine
Saldanha Bay
Berg R
Dassen Island
Cape Town
Hout Bay
False Bay
Walker Bay
Gans Bay
Breede R
Cape Point
Cape Infanta
Cape Agulhas
No fishing
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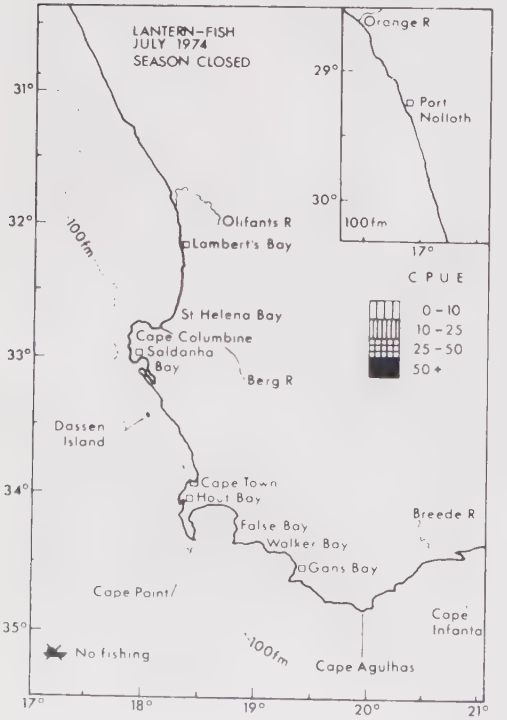
LANTERN-FISH
JULY 1974
SEASON CLOSED
Orange R
Port Nolloth
100fm
CPUE
0-10
10-25
25-50
50+
Olifants R
Lambert's Bay
St Helena Bay
Cape Columbine
Saldanha Bay
Berg R
Dassen Island
Cape Town
Hout Bay
False Bay
Walker Bay
Gans Bay
Breede R
Cape Point
Cape Infanta
Cape Agulhas
No fishing
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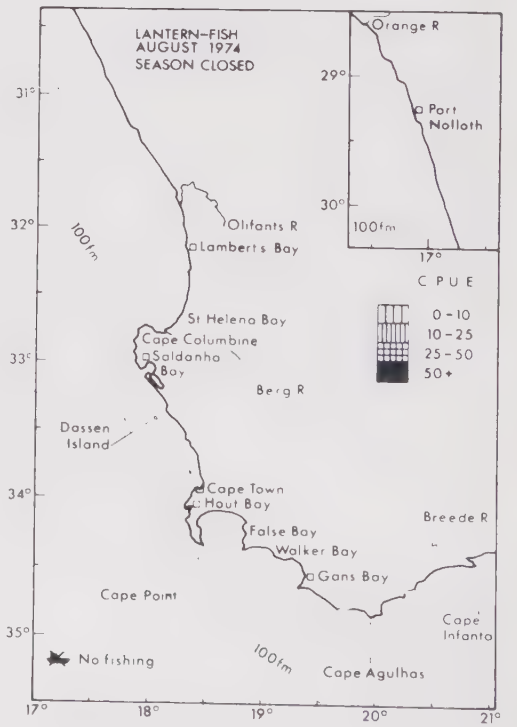
LANTERN-FISH
AUGUST 1974
SEASON CLOSED
Orange R
Port Nolloth
100fm
CPUE
0-10
10-25
25-50
50+
Olifants R
Lambert's Bay
St Helena Bay
Cape Columbine
Saldanha Bay
Berg R
Dassen Island
Cape Town
Hout Bay
False Bay
Walker Bay
Gans Bay
Breede R
Cape Point
Cape Infanta
Cape Agulhas
No fishing
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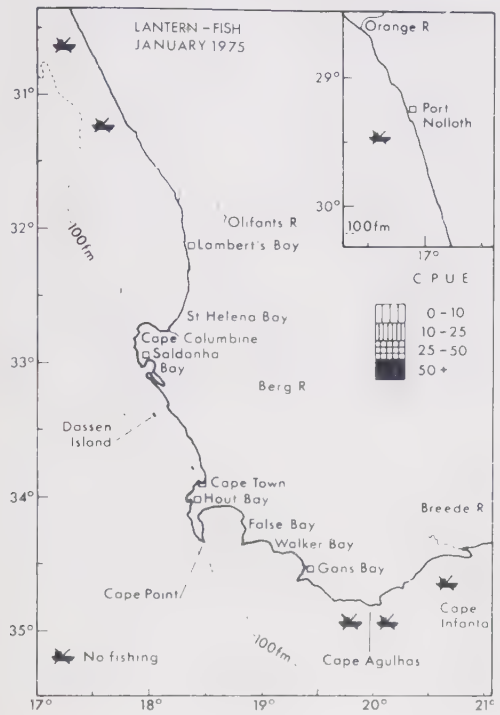
LANTERN – FISH
JANUARY 1975
Orange R
Port Nolloth
100fm
Olifants R
Lambert's Bay
St Helena Bay
Cape Columbine
Saldanha Bay
Berg R
Dassen Island
Cape Town
Hout Bay
False Bay
Walker Bay
Gans Bay
Breede R
Cape Point
Cape Infanta
Cape Agulhas
No fishing
C P U E
0 – 10
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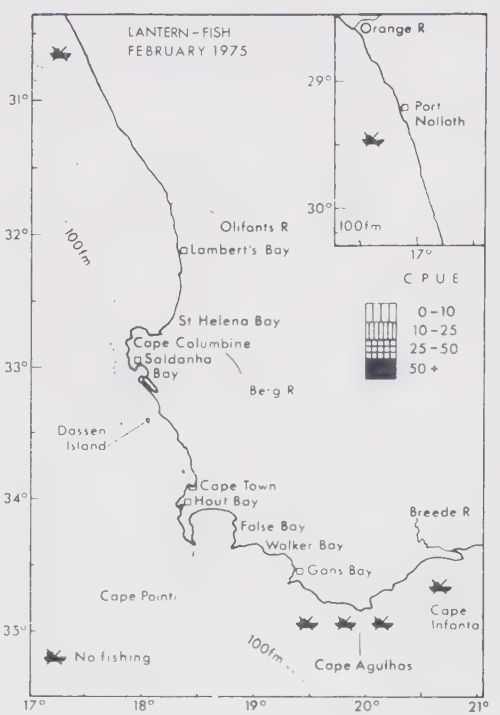
LANTERN – FISH
FEBRUARY 1975
Orange R
Port Nolloth
100fm
Olifants R
Lambert's Bay
St Helena Bay
Cape Columbine
Saldanha Bay
Berg R
Dassen Island
Cape Town
Hout Bay
False Bay
Walker Bay
Gans Bay
Breede R
Cape Point
Cape Infanta
Cape Agulhas
No fishing
C P U E
0 – 10
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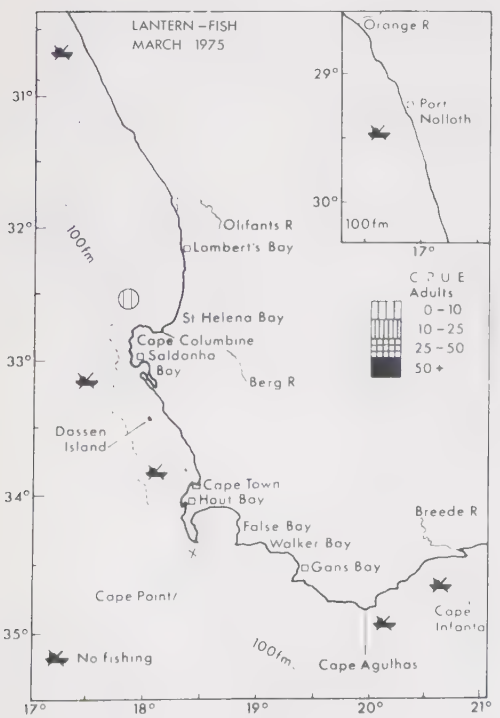
LANTERN – FISH
MARCH 1975
Orange R
Port Nolloth
100fm
Olifants R
Lambert's Bay
St Helena Bay
Cape Columbine
Saldanha Bay
Berg R
Dassen Island
Cape Town
Hout Bay
False Bay
Walker Bay
Gans Bay
Breede R
Cape Point
Cape Infanta
Cape Agulhas
No fishing
C P U E
Adults
0 – 10
10 – 25
25 – 50
50 +
31°
32°
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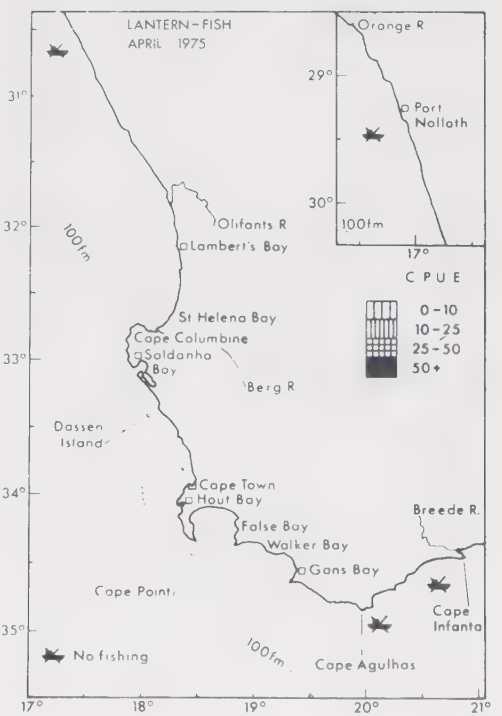
LANTERN – FISH
APRIL 1975
Orange R
Port Nolloth
100fm
Olifants R
Lambert's Bay
St Helena Bay
Cape Columbine
Saldanha Bay
Berg R
Dassen Island
Cape Town
Hout Bay
False Bay
Walker Bay
Gans Bay
Breede R.
Cape Point
Cape Infanta
Cape Agulhas
No fishing
C P U E
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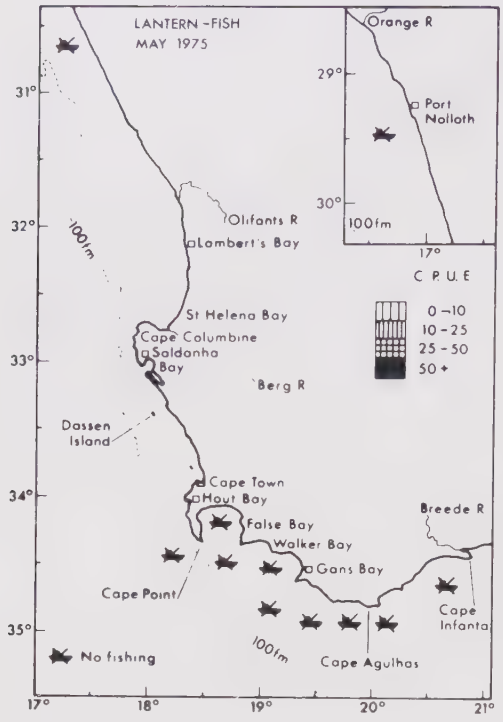
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Saldanha Bay
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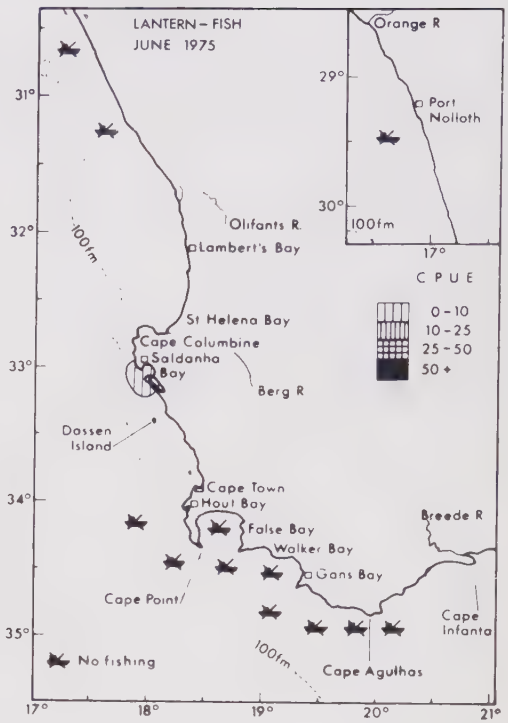
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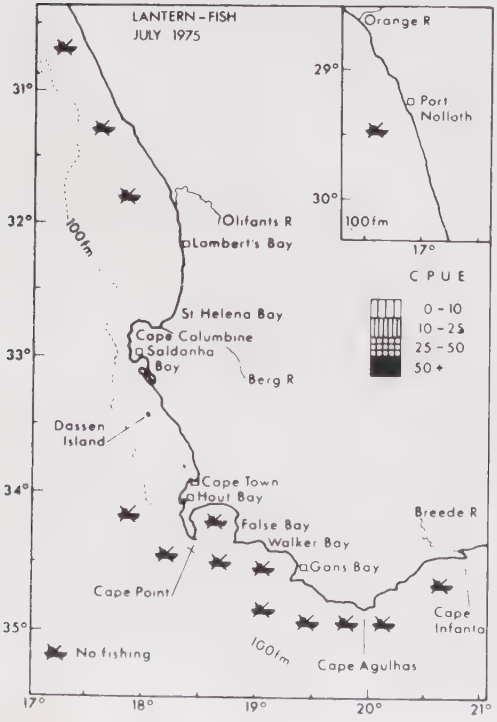
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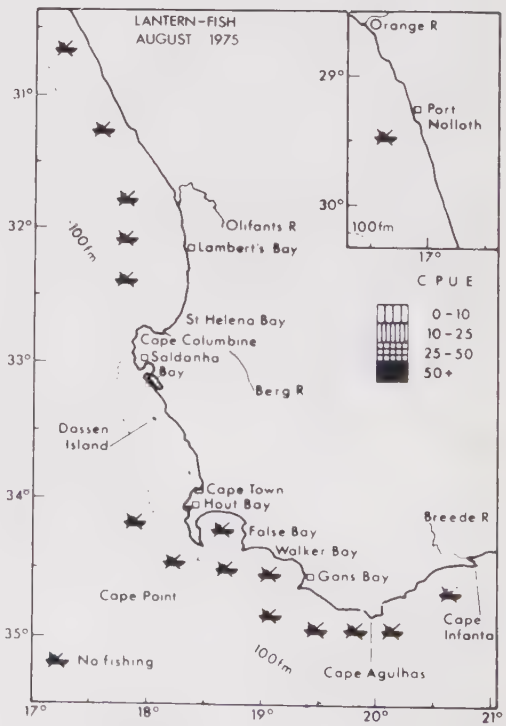
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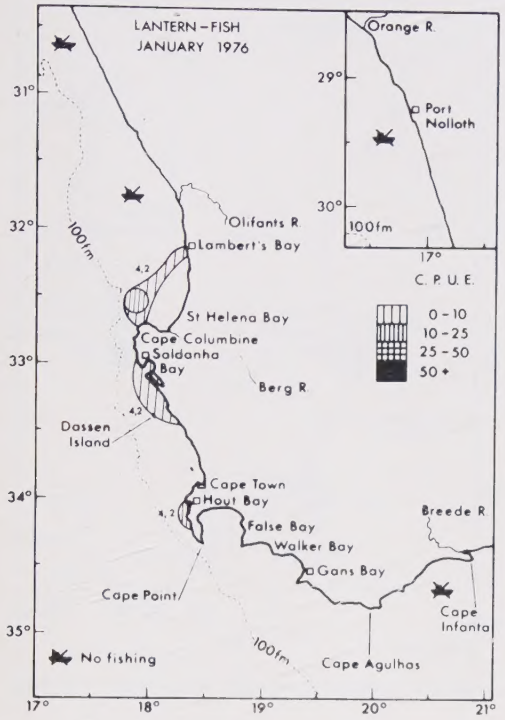
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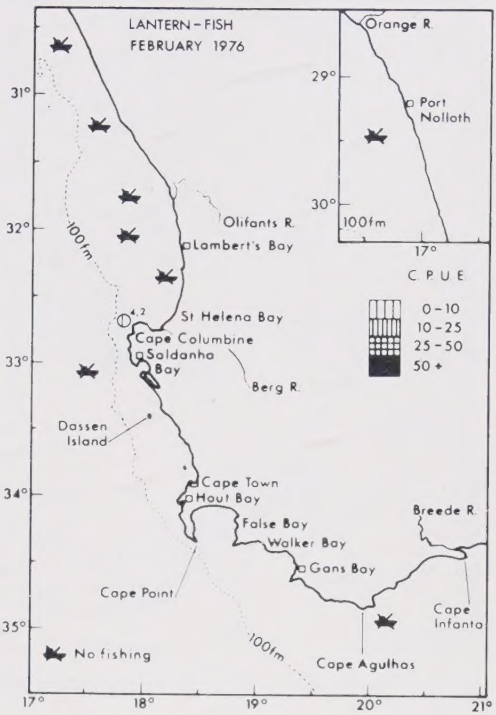
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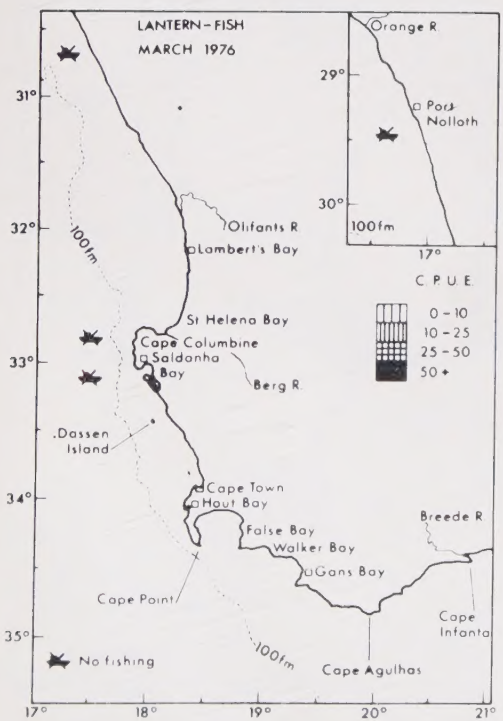
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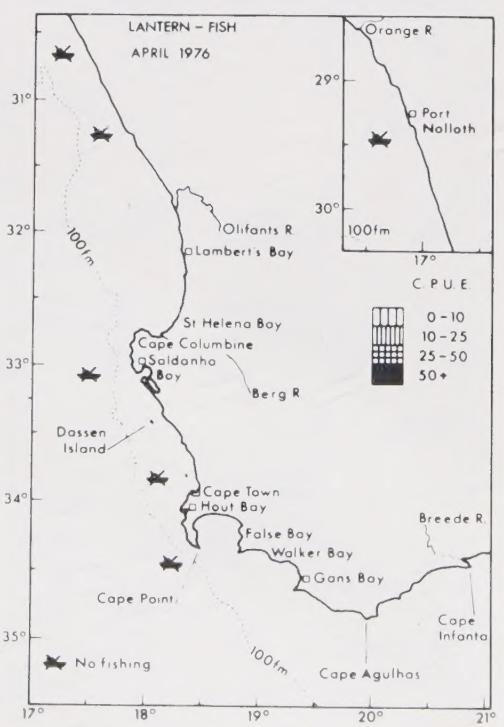
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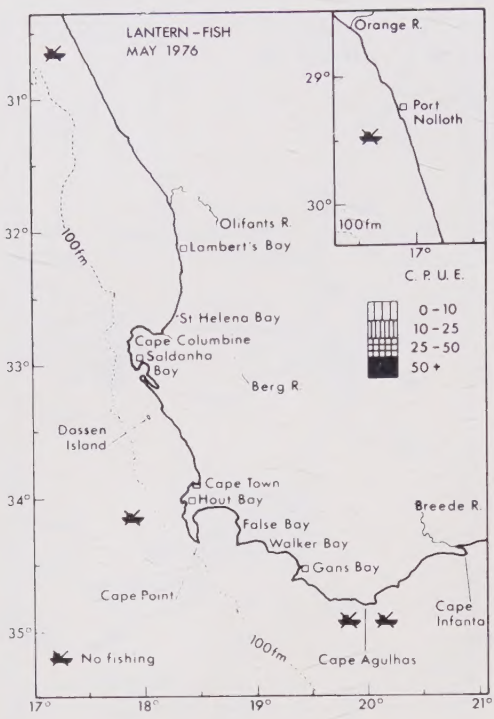
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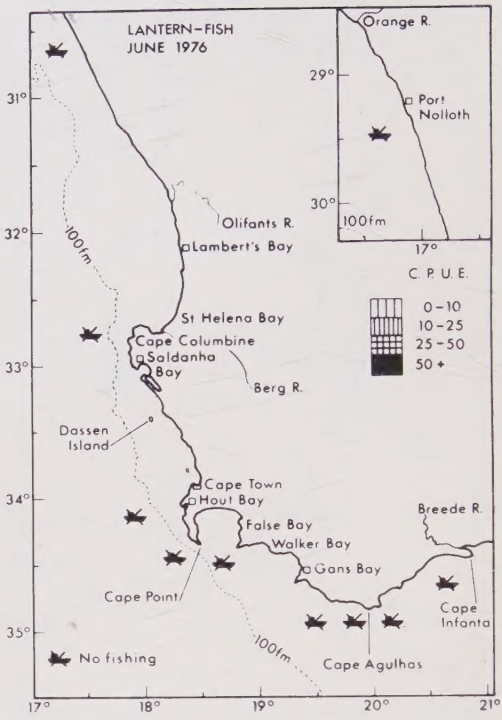
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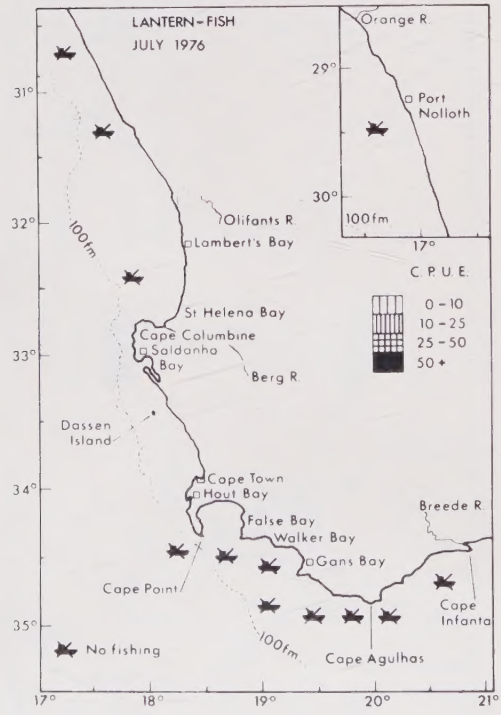
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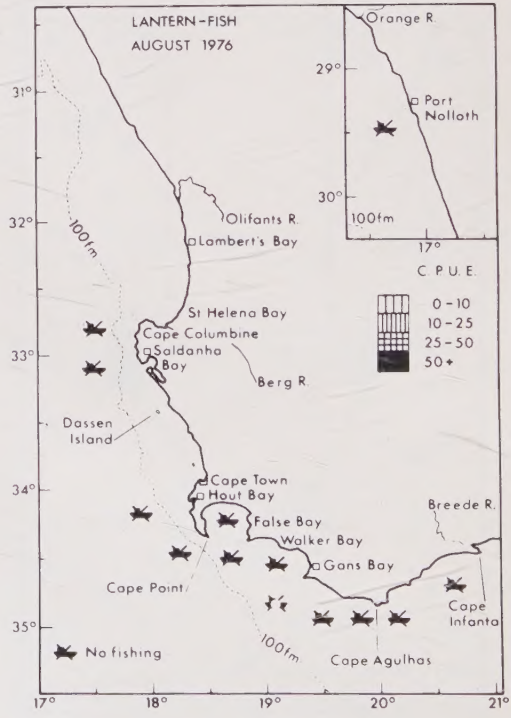
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1980
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